DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MATERIAL RECOVERY FROM USED CABLES IN TURKEY

by
Cengiz YURTTUTAN

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MATERIAL RECOVERY FROM USED CABLES IN TURKEY

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"MATERIAL RECOVERY FROM USED CABLES IN TURKEY"** completed by **CENGİZ YURTTUTAN** under supervision of **ASSIST. PROF. DR. GÖRKEM AKINCI** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ASSIST. PROF. DR. GÖRKEM AKINCI

Supervisor

....

(Jury Member) (Jury Member)

Prof.Dr. Cahit HELVACI

Director

Graduate School of Natural and Applied Sciences

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CENGİZ YURTTUTAN

MATERIAL RECOVERY FROM USED CABLES IN TURKEY

ABSTRACT

The aim of this study is to define the material recovery capacity from used cables in Turkey, in details. Also, general instructions about cable recovery are given to support the base of the thesis.

For this purpose, at first, cable manufacturing process is explained. One of the key components of a wire is its insulation. Its selection is determined by a number of factors. There are major types of materials used in a cable which are; resins, plasticizers, stabilizers, flame retardants, fillers, lubricants, and colorants.

Since there are a lot of different types of cables are in use, variety of used cables presence in recycling circle, too. These cables are classified according to their energy value, telecommunication uses, and their special uses.

During the experimental part of the study; each type of cable is divided into its components and weight percent of each different material used is determined gravimetrically for unit length of the cable. Then the calculated theoretical material recovery ratio for each type of used cable is found to determine the market capacity in Turkey by using the data obtained from cable manufacturers that shows annual cable production in the county.

Keywords: used cable, recovery, manufacture, classification

TÜRKİYE'DE KULLANILMIŞ KABLOLARDAN MADDE GERİ KAZANIMI

ÖZ

Bu çalışmanın amacı, Türkiye'de kullanılmış kablolardan malzeme geri kazanım kapasitesini detayları ile belirlemektir. Ayrıca, kablo geri kazanımı hakkında genel açıklamalar da tezin esasını desteklemek amacıyla verilmektedir.

Bu amaçla, ilk olarak kablo üretim prosesi açıklanmaktadır. Kablo telinin ana bileşenlerinden birisi onu çevreleyen kaplamasıdır. Kaplamanın seçimi pek çok faktörlere göre belirlenir. Bu önemli materyaller reçineler, plastikleştiriciler, stabilizasyon, alev geciktiriciler, dolgu maddeleri, yağlar ve renk vericilerdir.

Kullanılan farklı tip kabloların olmasından beri çeşitli kullanılmış kablolar geri dönüşüm çemberinde de gösterilmektedir. Bu kablolar enerji değerine, telekomünikasyonda kullanılmasına ve diğer özel kullanımlara göre sınıflandırılmaktadır.

Çalışmanın deneysel kısmında her tip kablo, kablonun birim uzunluğu dikkate alınarak kullanılan her farklı malzeme kendi içinde, bileşenleri ve yüzde ağırlıklarına göre gravimetrik olarak belirlenmiştir.

Daha sonra her tip kablo için hesaplanan teorik malzeme geri kazanım oranı Türkiye'deki kablo üreticilerinden elde edilen yıllık kablo üretim kapasitesi ile kıyaslanarak pazar kapasitesi hesaplanmıştır.

Anahtar sözcükler:
Kullanılmış kablo, geri kazanım, üretim, sınıflama

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CHAPTER ONE

LITERATURE SURVEY

1.1 Introduction to Cables

Cable products are critical to the modern economy. Their application is increasing with the growing use of computers, the internet, cable television, and the increase in electrical power service worldwide. Each type of cable, however, has several common elements including the core (typically copper or fiber optic), insulation, and jacketing (see Figure 1.1).

Figure 1.1 Typical cable

1.1.1 Cable Manufacturing Process

The manufacturing of cable is a multi-stage process. Raw materials are combined in a series of manufacturing steps including resin and additive manufacturing, resin compounding, wire drawing (or fiber optic), extrusion, cabling, and jacketing.

Polymers and additives are combined together in a compounding operation to produce materials formulated to meet the various insulation or jacketing performance requirements (e.g., heat and light stability, smoke retardancy, or water resistance). Once the additives have been combined with the polymer resin, the resulting material typically goes through re-heating and cooling to produce small, hard pellets. These pellets are later re-melted in extrusion equipment to insulate or jacket wire and cable.

The core of the product is a metal (usually copper or aluminum) rod or fiber optic preform that is drawn down to a specified diameter. The process of “drawing” wire involves reducing the diameter of the core by pulling it through a converging set of dies until it reaches the specified size. Some products then require various drawn wires to be bundled together. Fiber optics use a different process involving an atmospheric controlled furnace to melt the preform and draw it to the specified diameter.

Plastic compound is then extruded over the core to provide jacketing or insulation. When plastic covers bare electric wire, the coating is called primary insulation. A secondary layer of plastic extruded over a wire or a group of wires is called a sheath or jacket. Extrusion is the process of melting, feeding, and pumping a polymeric compound through a die to shape it into its final form around the wire. Depending on the desired performance characteristics, the insulated wires are often combined, or cabled, in various configurations. A critical requirement is that the melt leaving the die is very uniform. Another critical requirement is that the line must be capable of running the wire or cable with uniform tension at a desired but constant speed without variation or drift. The lines are commonly designed for a range of different wires and cables (Rosato, 1998).

Wire and cable coverings are tested in-line generally more than any other extruded product because they are rather inaccessible for many tests when wound on a reel. Spark testing is very common. The wire passes through a high-voltage field, and if there are any breaks, pinholes, or thin spots in the covering, a circuit is completed to the conductor and a signal of some type is produced. In addition, some measurements are made to ensure conformance to specifications (e.g., diameter, capacitance and eccentricity measurements). Finally the cable is wound onto reels and shipped to a job site or retailer.

1.1.2 Cables Insulation

One of the key components of a wire is its insulation. Its selection is determined by a number of factors such as stability and long life, dielectric properties, resistance to high temperature, resistance to moisture, mechanical strength, and flexibility. There is no single insulation that is ideal in every one of these areas. It is necessary to select a cable with the type of insulation, which fully meets the requirements of the application. Jackets cover and protect the enclosed wires or core against damage, chemical attack, fire and other harmful elements that may be present in the operating environment.

There are seven major types of materials used in coated wire and cable (see list below). Each material type is reviewed in the following subsections.

1. resins (thermoplastic and thermoset compounds) for insulation and jacketing;
2. plasticizers to make the plastic flexible and easy to process (and impart other qualities such as impact resistance and abrasion resistance);
3. stabilizers to provide heat resistance during manufacturing as well as visible light, UV-rays and heat resistance during product use;
4. flame retardants to slow the spread of an accidental fire and reduce the amount of heat and smoke released
5. fillers to reduce formulation costs and improve insulation resistance;
6. lubricants to improve the ease of processing; and
7. colorants to give the desired color, which is crucial for identification purposes.

Table 1.1 and Table 1.2 present the basic materials used in the two most common wire and cable coatings – polyethylene and polyvinyl chloride. Table 1.1 outlines several polyethylene wire and cable formulations (polyethylene, cross linked polyethylene, and chlorinated polyethylene) for power cable applications.

Table 1.2 outlines typical polyvinyl chloride formulations for different applications. The types of materials used in a wire and cable depend largely on the specific resin system (e.g. thermoset polyethylene versus cross-linked polyethylene versus polyvinyl chloride) and the application (i.e., plenum rise communications wire versus high voltage power cable). When reviewing the formulations in Tables 1.1 and 1.2, note that:

- The formulations are presented in phr (parts per hundred resin) – a common way to present wire and cable formulations. To convert to weight percent, divide individual phr by total number of parts. Multiply this factor by 100 to get weight percent.

- The formulations are designed to meet Underwriter Laboratory (UL) test specifications.
- The formulations are generic and would require adjustments for specific applications.
- Some of the ingredients use trade names

Table 1.1 contains three different polyethylene formulations for a power cable. Power cable examples are used because the applications are most often flame retardant. The Underwriters Laboratory designation UL denotes “thermoset-insulated wire and cables”. Wires marked “VW-1” comply with a vertical flame test. UL-94 references a test for flammability of plastic materials for parts in devices and appliances; V-0 is the highest flammability rating.

Table 1.1 Various Polyethylene Power Cable Insulation Compositions

Crosslinked Polyethylene UL-44 VW-1		
Low Density Polyethylene (Resin)	90	phr
EVA-LDPE (Resin)	10	phr
N550 Carbon Black (Filler)	25	phr
Saytex BT-93 (Brominated Flame Retardant	30	phr
Sb_2O_3 (Flame Retardant)	12	phr
Phenolic Antioxidant (Stabilizer)	2	phr
MgO (Stabilizer)	2	phr
Vinyl Silane	1	phr
Calcium Stearate (lubricant)	1	phr
Teflon 6C	2	phr
Vul-Cup Peroxide	2	phr
TATM	1	phr

Source: Albemalre Web Site (http://www.albemarle.com/saytexfr_wire.htm)

Table 1.1 Various Polyethylene Power Cable Insulation Compositions (continues)

Thermoplastic Chlorinated Polyethylene UL-44 VW-1		
Chlorinated Polyethylene (42%) (Resin)	90	phr
Medium Density Polyethylene (Resin)	30	phr
Washed Clay (Filler)	25	phr
N550 Carbon Black (Filler)	25	phr
Red Lead (Stabilizer)	9	phr
Epoxy Stabilizer (Stabilizer)	3	phr
Hydroquinone Antioxidant (Stabilizer)	2	phr
Saytex BT-93 (Brominated Flame Retardant)	30	phr
Sb2O3 (Flame Retardant)	15	phr

Source: Albemalre Web Site (http://www.albemarle.com/saytexfr_wire.htm)

Table 1.1 Various Polyethylene Power Cable Insulation Compositions (continues)

Thermoplastic Polyethylene UL-94 V-0 / UL-44 VW-1		
Polyethylene (Resin)	100	phr
Talc (Filler)	575	phr
Saytex 102 (Brominated Flame Retardant)	23	phr
Sb2O3 (Flame Retardant)	115	phr

Source: Albemalre Web Site (http://www.albemarle.com/saytexfr_wire.htm)

Table 1.2 depicts the material composition for different wire types. In general, the UL letter designations provide information on intended use, insulation type and insulation temperature rating. For example, T: thermoplastic insulation; H: 75°C temperature rating; HH: 90°C temperature rating W: moisture resistant; and N: nylon jacketing. Table 1.2 shows how composition changes for different wire types.

Table 1.2 Various Polyvinyl Chloride Insulation Compositions

UL Designation	T-TW	THW-THWN	NM-B	THH-THHN	Units
Temperature Rating	60°C	75°C	90°C	90°C	phr
Polyvinyl Chloride (Resin)	100	100	100	100	phr
DiIsoDecyl Phthalate (Plasticizer)	45	35			phr
Ditridecyl Phthalate (Plasticizer)		15	30	20	phr
Tri Octyl Trimellitate (Plasticizer)			15	35	phr
CaCO3 (Filler)	20	20		15	phr
Clay (Filler)	10	10	7	15	phr
Wax	0.5	0.3	0.5	0.3	phr
Bisphenol A (stabilizer)			0.2	0.3	phr
Sb2O3 (flame retardant)				3	phr
Tribasic lead sulfate (stabilizer)	4	5			phr
Basic lead sulfophthalate (stabilizer)			6	7	phr

Source: "Handbook of PVC formulating", edited by Edward J. Wickson, 1993 (Publisher: John Wiley & Sons

1.1.2.1 Resins

Polyethylene and PVC are the principal resins used in the wire and cable industry. In Canada, for example, PVC makes up 60% of the market, polyethylene – 34% and numerous other resins comprise the remaining (6%). In U.S., however, polyethylene and its copolymers is the primary resin, followed by PVC, nylons, fluoropolymers and others.

Table 1.3 presents data for the 2000 volume of thermoplastic resins used in wire and cable (BCC 2000, P-133R).

Table 1.3 Volume of US thermoplastic resins in wire and cable – 2000

Thermoplastic resin	**Million lb.**	**Percent**
Polyethylene and copolymers	578	46%
PVC	486	39%
Nylons	74	6%
Fluoropolymers	50	4%
Polypropylene	16	1%
Other	53	4%
Total	1257	100%

Source : BCC, Inc. 2000 P-133R

Table 1.4 presents the U.S. volume of polyethylene and PVC by application for 2000 (BCC 2000, P-133R). Either polyethylene or PVC is the leading resin system for every type of application. The building wire and cable market uses the greatest volume of polyethylene (96,036,000 kg.), while the electric segment uses the greatest volume of PVC (74,745,000 kg.) In total, polyethylene and PVC comprise 85% of the thermoplastic wire and cable resin market.

Table 1.4 Volume of Polyethylene and copolymers and PVC resins in U.S. wire and cable - 2000

Application	PVC (million lb.)	Polyethylene & CoPolymers (million lb.)	Polyethylene & Copolymers and PVC (percent of total pounds of thermoplastic)	Total Pounds of Thermoplastics (million lb.)
Building	212	81	89%	329
Electric	73	165	85%	280
Telephone and Telegraph	73	48	89%	136
Fiber Optic Wire Cable	65	75	72%	194
Apparatus	26	54	88%	91
Power Distribution	21	96	93%	126
Magnetic	5	22	93%	29
Other	11	37	67%	72
TOTAL:	486	578	85%	1257

Source : BCC, Inc. 2000 P-133R

The factors affecting the quality and strength of a cable are as follows; temperature range, water resistance, flame resistance, heat resistance, abrasion resistance, electrical properties (insulation), ozone resistance, flexibility, tear/impact, uv resistance, strength/mechanical strength, and solvent resistance.

This section focuses mainly on these two resins and just briefly mentions other resins used for insulation and jacketing. Each selected resin for wire and cable needs to meet various performance requirements.

Polyethylene is a lightweight, water-resistant, chemically inert, and easy to strip resin. The different types of polyethylene used in the wire and cable industry include low-density (LDPE), linear low-density (LLDPE), medium-density (MDPE), high-density (HDPE), chlorinated polyethylene (CPE) and cross-linkable polyethylene (XLPE).

Table 1.5 Polyethylene types

Type	**Notes**
LDPE	Used in jacketing and insulation.
LLDPE	Has superior tensile strength and abrasion resistance
MDPE	When blended with LDPE, imparts stiffness and abrasion resistance
CPE	Contains 25% - 42% chlorine; used in jacketing due to toughness and flame retardancy
XLPE	Cross linked LDPE, usually with organic peroxides

Source: Albemalre Web Site (http://www.albemarle.com/saytexfr_wire.htm)

Polyethylene's low dielectric constant allows for low capacitance and low electrical loss making it the choice for audio, radio frequency, and high voltage applications. In terms of flexibility, PE can be rated stiff to very hard, depending on molecular weight and density. The resin has excellent moisture resistance and can be compounded to make it flame retardant. However, PE is less inherently flame retardant than other resin systems such as polyvinyl chloride and fluorinated ethylene-propylene. Therefore, polyethylene resins are often compounded (e.g., with brominated flame retardants, antimony oxide, etc.) to make them more flame retardant. PE is used in nearly all types of wire and cable products such as electronic, telephone and telegraph, power distribution, fiber optic, and building wire and cable products.

In Europe the market has accepted the use of non-halogen flame retardant PE and moisture-cured XLPE for insulation and jacketing in some flexible cords, appliance wires, building wire and many other end uses. The use of inexpensive aluminum trihydrate ($Al(OH)_3$) flame retardant additive is quite common. Calcium carbonate can also be used as a filler to provide a PE compound that is price-competitive with PVC compounds. Some companies, like IKEA of Sweden, have developed with their own specifications and converted appliance cords to non-halogenated PE alternatives.

Polyvinyl chloride (PVC) finds use in virtually all of the major types of wire and cable: low voltage building wire insulation and jacketing, low and medium voltage equipment cable jacketing, control cable jacketing, indoor telecommunications cable, automotive wire and flexible cords. It is an inherently flame and abrasion resistant material that is specially compounded for general-purpose applications at temperatures to 105 °C. It resists flames, oil, ozone, sunlight, and most solvents.

Wire and cable accounts for roughly 68% of PVC use in electrical products or about 592 million pounds in 1999 (CEH 2001, 158.1881 M). PVC's greatest uses are in building wire, and its second greatest use is in electronics and telecommunications.

Demand growth for PVC use in electrical applications will be negligible (~2%) according to the 2001 Chemical Economics Handbook (CEH 2001, 580.1881 N). The wire and cable industry will be impacted by several technological trends that can reduce the growth of polymer usage in general. For example, fiber-optic cable is replacing copper cable in many applications. Fiber optic wire and cable requires less polymer than those made of copper because of reduced cable thickness. The proliferation of wireless communications technology, such as cellular, microwave and satellite communications, can reduce the need for premise wiring and, consequently, resin consumption. Even if these trends prove to have a minor impact on polymer usage, PVC growth in electrical uses is expected to be minimal because of competition from other polymers such as ethylene-propylene elastomers, thermoplastic elastomers and polyolefins. These trends are expected to keep growth in PVC consumption for electrical applications to about 2% per year through 2004 (CEH 2001, 580.1881).

PVC is typically used for cable inside buildings, due to its superior flexibility and flame retardant properties. Flame and smoke retardancy is critical in plenum space (above ceilings and/or below raised floors) of buildings, when air from this area is returned through ventilation systems to heating or air conditioning units and redistributed by fans throughout a building or plant. Currently PVC and FEP (fluoropolymers) are the two resins that can meet the strict fire safety requirements for plenum cables.

The principal technical characteristic that differentiates PVC and polyethylene (PE) wire and cable is the flame retardant qualities of PVC resin. Fire code specifications aim to ensure that insulation and jacketing materials are sufficiently flame resistant to delay the spread of fire long enough for people to safely evacuate a building. The presence of chlorine in the molecular structure of PVC resin, accompanied by synergists such as antimony trioxide, gives the material a much higher flame resistance than other thermoplastics such as PE. For this reason, PVC compounds are typically chosen as an inexpensive jacketing material in many interior wire and cable applications.

There are some reports of substitutions of other resin systems for PVC in the literature. For example, a 1997 report by Environment Canada reviewed the socio-economic and technical importance of products derived from the chlor-alkali industry, and options to reduce these products. Part of the report examined polyvinyl chloride in wire and cable products. The report noted an increase in the adoption of low- or zero-halogen PE resins in jacketing for new and replacement electrical and telecable installations in transit systems, shipboard systems, major commercial and institutional buildings and telephone switching stations (Environment Canada 1998). The report also noted:

- Switching from PVC-nylon insulation to moisture-cured cross-linked polyethylene (XLPE) in the NMD-90 residential building wire niche.
- In Europe, PVC has been replaced in a few wire and cable applications. The European market has accepted the use of non-halogen flame retardant PE and moisture-cured XLPE for insulation and jacketing in some flexible cords, appliance wires, and building wire uses.

Fluorinated ethylene-propylene (FEP) is a melt-processible copolymer of tetrafluorethylene and hexafluoropropylene. FEP has exceptional dielectric properties in addition to excellent chemical inertness, heat resistance, weather resistance, and toughness and flexibility. An example of FEP is Teflon (DuPont trademark). In the United States, the majority of FEP is supplied by DuPont, the only U.S. producer. The leading market for FEP is the manufacture of plenum wire and cable. More than 95% of the FEP that is employed in this market is used as primary insulation.

The remainder is used as a jacketing material. FEP will continue to experience good growth in this market sector because its superior electrical properties make it the preferred material for primary insulation in the rapidly growing data transmission segment of the plenum wire market (Chemical Economics Handbook, 2001).

Other resins: Small amounts of other materials are used as insulation and jacketing for wire and cable manufacturing. These typically include nylon, polypropylene, styrenics, acrylic, thermoplastic elastomers.

1.1.2.2 Plasticizers

Plasticizers make vinyl and other plastics flexible even at low temperatures and also provide mechanical properties, impact resistance and abrasion resistance. Their market is dominated by the PVC processing industry, which, according to different estimates, accounts for between 80 and 90% of demand (Wilson 2000). Polyethylene resins systems, for example, do not require plasticizers to increase flexibility.

Dioctyl phthalate (DOP or di-2-ethylhexylphthalate (DEHP)) is used in larger quantities in PVC than any other plasticizer. Both technically and commercially, DEHP is the reference point for assessment of other plasticizers. It is technically interchangeable to a large extent with the other major phthalates -- DIDP (diisodecyl phthalate) and diisononyl phthalate (DINP). DEHP’s limitations include higher volatility and migration.

DIDP is much less volatile than DEHP, both in PVC processing and in end product service at elevated temperatures. It is the main plasticizer used in cables since it ensures conformance with a wider range of end use specifications than DEHP. However, it has lower plasticizing efficiency than DEHP and needs to be used at higher levels to give matching softness and requires higher temperatures when processed (Wilson 2000).

DINP is intermediate between DEHP and DIDP in all aspects of performance. It is the plasticizer that is most likely to be considered as a DEHP substitute either for commercial reasons or because users wish to avoid the health and safety questions associated with DEHP.

While there are numerous other types of plasticizers, there are few applications in the wire and cable industry. For example, adipates and sebacates confer far better cold flex and are usually classified functionally as low temperature plasticizers. But their high price tends to limit their use to special applications (e.g., military). Although still a small percent of the market, citrate and polyester plasticizers are currently emerging as viable substitutes for phthalates.

Advances in citrate technology and use are paving the way for their wider adoption. Morflex already has grades for plastic tubing and toys, and claims suitable citrates can be developed for virtually all flexible PVC markets, including wire and cable. Their cost is also expected to go down with improvements in the patented technology. Citric acid esters are made out of citric acid (made by fermentation from a biomass), which is biodegradable, as are other ingredients of the chemical. Also, citrates are approved by the U.S. Food and Drug Administration in current non-plastic uses such as coatings for tablets, fragrances, and cosmetic products like shampoos (Modern Plastics 2000).

Another group of important phthalate alternatives is polyester plasticizers such as PX-811, a product developed by Japan’s Asahi Denka Kyogo K.K., Tokyo. This plasticizer is claimed to outperform competing citrate plasticizers in key criteria, notable heat aging, oil extraction, and low-temperature performance. Its volatility is lower compared to citrates and this leads to lower in-plant emissions. Finally, the manufacturer claims that the material is significantly less costly than existing citrate plasticizers (about $3.31/kg) (Modern Plastics 2000).

Regardless of these developments, industry sources note that 85% of all flexible PVC worldwide still uses phthalates as plasticizers and there is no sign of a broad trend away from them.

1.1.2.3 Stabilizers

Stabilizers are added to guarantee heat resistance during manufacturing, and to elevate the resistance of products against external impacts likemoisture, visible light, UV-rays and heat. PVC currently accounts for virtually all of the heat stabilizer consumption (99% of the world consumption) (Chemical Additives For Plastics 1999). Note that this figure does not include elastomerics.

PVC resin begins to degrade at temperatures of roughly 160 °C via dehydrochlorination. Since PVC is generally processed at temperatures between 160 °C and 210 °C, stabilizers are necessary to manufacture PVC resin products such as wire and cable (see Figure 1.2). Figure 1.2 shows the PVC heat degradation relationship between chlorine generation and temperature (Mizuno et. al. 1999). There are four major types of primary heat stabilizers:

- Lead compounds
- Mixed metal salt blends
- Organotin compounds
- Organic compounds

Lead compounds are the predominant stabilizer in wire and cable worldwide as a result of its cost-effectiveness and excellent electrical insulation properties (e.g., for wet applications). PVC is the only plastic material in which lead is commonly used as a stabilizer. The compounds used include tribasic lead sulfate, dibasic lead phthalate, dibasic lead stearate, lead stearate, lead phosphite, carbonate lead derivatives, etc.

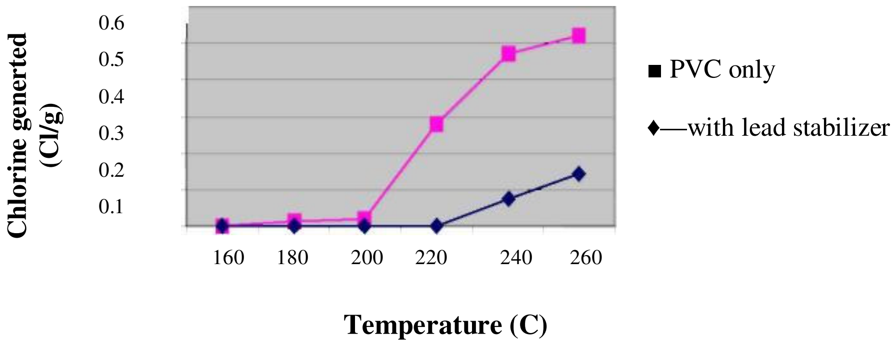


Figure 2: Heat Degradation of PVC

One advantage of lead stabilizers is that the lead chloride produced during the stabilization process does not promote dehydrochlorination. Lead stabilizers also give PVC excellent wet electrical characteristics. On a weight basis, lead compounds typically constitute 2-5% by weight of PVC wire insulation or jacketing.

Mixed metal salt blends are primarily used in flexible or semi-rigid PVC products. The most common are barium/zinc (Ba/Zn) and calcium/zinc (Ca/Zn) metal salts (Ba/Cd has been phased out due to cadmium toxicity concerns). Furukawa Inc. has developed an Al/Mg/Ca/Zn stabilizer.

Organotin compounds are used primarily for rigid PVC applications. Sulfur-containing organotin compounds are currently the most efficient and most universally used heat stabilizer among all organotins. Organotin mercaptides (with at least one tin-sulfur bond) not only are able to react with hydrogen chloride but they also help impede autoxidation. The combination of these two functions gives the organotin mercaptides exceptional thermostabilizing properties, which are not exceeded by any other class of stabilizer. Organotin heat stabilizers are seen as potential replacements for lead in PVC wire and cable applications (Gachter and Muller 1993).

Organic compounds (completely metal-free) are a new entry in the market and the subject of intense development by the major heat stabilizer producers. Several types are being evaluated including organosulfide products and heterocyclic compounds. Although their usage is still very low, they could become a significant factor in the market in response to the pressures to replace cadmium, lead, barium and even zinc in heat stabilizers. There is a significant R&D effort to develop organic stabilizers at the expense of the metallic types (e.g., Witco, Morton and Ferro). By 2003 these stabilizers may account for 2% of total global market (Chemical Additives for Plastics 1999).

1.1.2.4 Fillers

Fillers are used in most resin systems (including PVC and polyethylene) to reduce formulation costs and improve the insulation's electrical resistance. Typical filler materials include precipitated calcium carbonates, ultra fine ground calcium carbonate and dolomite, fine ground, refined and micronised talcs, micas, silica, carbon black, china clays (kaolin) and wollastonite. "Filler" is a somewhat misleading term since it connotes that the material has no functional value. In fact, fillers are carefully chosen since they can significantly impact the resin system – by increasing tensile strength (carbon black), reducing costs (clays and talcs), and affecting electrical and other properties.

1.1.2.5 Flame Retardants

Flame-retardants are used in wire and cable compounds to slow the spread of an accidental fire and reduce the amount of heat and smoke released. During combustion of wire and compound materials, free radicals are formed by pyrolysis. The radicals then combine with oxygen and a chain reaction ensues. Combustion is slowed or stopped when the oxygen -radicals chain reaction is interrupted. There are five major methods for making polymer systems fire retardant (Othmer 1985).

At the molecular level, dehydrochlorination causes the formation of double bonds, the cutting of molecular chains, and cross-linking, resulting in reduced processability, mechanical strength and electrical properties.

Raise the decomposition temperature of the polymer – generally by increasing polymer cross-linking density;

1. Reduce the fuel content of the system – e.g., by halogenating the polymer backbone, adding inert fillers, or employing organic systems;

2. Induce polymer flow – for thermoplastics interrupting the polymer backbone to reduce viscosity and promote dripping;

3. Induce selective decomposition pathways – e.g., use of phosphorous compounds in cellulose materials where phosphoric acid is generated, resulting in the loss of water and the retention of carbon as char which acts a physical heat and gas flame barrier; and

4. Mechanical/other means such as bonding non-flammable skins, employing sprinklers, etc.

The three primary classes of flame-retardants are halogenated compounds, inorganic compounds (including antimony), and phosphorous compounds. Chemically acting flame retardants (such as the halogenated bromine and chlorine systems) are very effective. Physically acting inorganic flame-retardants based on metal hydroxides and salts have a weaker effect. The performance of primary flame retardants such as chlorine, bromine and phosphorous is enhanced by additives such as antimony, zinc and other metal salts. Antimony oxide is typically used in flexible PVC wire and cable type products. Rigid PVC products are essentially flame retardant due to their chlorine content. Plasticized PVC (flexible) products contain large amounts of flammable plasticizers such as DIDP. For some applications, there is sufficient chlorine content in the PVC such that additional flame retardants are not required. However for applications that must meet more stringent flame tests, additional flame retardants are often used. (USAC 2001).

In general, flame retardants in the form of powder additives are mixed into the wire and cable compounds. They remain inert until high temperatures activate them – such as those generated by a fire. Table 1.6 estimates the volume and cost of flame-retardants used in wire and cable fabrication polymers. Cost estimates are for North America and are estimated average prices for the five major classes of flame-retardants.

Table 1.6 1998 Volume of Flame Retardants in US Wire and Cable

Type	1998 Volume (million lbs)	Percent	Cost ($/lb)
Organic bromine compounds	9	9%	1.40
Organic chlorine compounds	1	1%	1.35
Phosphorous compounds	5	5%	1.35
Inorganic flame retardants	81	84%	
Alumina trihydrate	70	73%	0.25
Antimony trioxide	7	7%	1.90
Other inorganics	4	4%	
Total	96	100%	

Source: BCC 2000 (Volume) and Townsend Tarnell (Cost)

1.1.2.5.1 Halogenated Flame Retardants. Halogenated flame-retardants include (1) bromine-containing flame retardants, (2) chlorine-containing flame retardants, and (3) halogen/antimony flame retardants.

Of chlorine and bromine the latter is more effective as a flame retardant since it has a weaker bonding to carbon, enabling it to interfere at a more favorable point in the combustion process. Bromine can be bound aliphatically or aromatically in flame retardants. Flame retardants with aromatically bound bromine have the highest market share. At moderate loadings they reduce the flammability of several polymeric materials used in wire and cable, such as polyolefins and neoprene rubber. Comparisons show that a UL-94 V0 fire rating is possible with 82% polyethylene, 12% decabromodiphenyl oxide, and 6% antimony oxide compound, whereas a 60% polyethylene, 27% chlorine, and 13% antimony oxide formulation yields a UL-94 V1 fire rating. Major brominated organic compounds used as wire cable flame retardants include decabromodiphenyl oxide (DBDPO), ethylene bis-tetrabromophthalimide, and tetradecabromodiphenoxy benzene (BCC 2000).

The chlorine present in PVC gives the cable a measure of inherent flame retardancy. However, additional flame-retardants are also usually added to such grades. Chlorinated flame retardants are used in plastics mainly in the form of chlorinated hydrocarbons or chlorinated cycloaliphatics. They are low cost and offer good light stability. To achieve the required flame retardancy, however, formulations with high amounts of the respective flame retardant are necessary. This can adversely affect the properties of the polymer (Gachter and Muller 1993). Therefore, a synergistic agent is often used. Antimony trioxide is such a widely used agent that produces a marked synergistic effect with halogen-containing compounds.

1.1.2.5.2 Inorganic Compounds. Very few inorganic compounds are suitable for use as flame retardants in plastics because they are usually too inert to be effective in the range of decomposition temperatures of plastics (between 150 and 400 °C). The most common types of inorganic flame retardants include alumina trihydrate (also known as aluminum hydroxide), antimony trioxide, and boron-containing compounds. One major disadvantage of inorganic flame retardants is hygroscopicity – non-halogens tend to pick up water and are sometimes compensated for by adding fillers such as clay which reduce water absorption. Pigmentation is also more difficult with non-halogenates.

To be effective, antimony oxides must be converted to volatile species. This is typically accomplished when halogenated organics release halogen acids in the presence of fire temperatures. The halogen acids react with the antimony-containing materials in the condensed phase to promote char formation. The latter acts as a physical barrier to flame and inhibits the volatilization of flammable materials in the flame in sufficient volume to provide an inert gas blanket over the substrate, supplanting oxygen and reducing flame spread. Antimony halides also alter fire-temperature chemical reactions in the flame, making it more difficult for oxygen to combine with volatile flame byproducts. The most effective flame-retardant system for polyethylene is an antimony oxide and a low melting halogen combination

Currently aluminum hydroxide (or also called alumina trihydrate ATH) is the most widely used inorganic flame retardant; it is low cost and easy to incorporate into plastics. When exposed to temperatures over 250°C, it forms water and alumina, with the evolution of water absorbing heat by cooling the flame, diluting the flammable gases and oxidant in the flame, and shielding the surface of the polymer against oxygen attack and thermal feedback. In wire and cable applications it is used in PVC, LDPE, EPDM and EVA. Recent studies have demonstrated that there are major advantages to using a combination of ATH and zinc borate in a variety of halogen-free polymer systems (combined filler and flame retardant functions, does not require halogens, does not produce toxic gases, low cost).

Magnesium hydroxide's main advantage over ATH is the higher decomposition temperature of 330-340 °C. Its main application is with polypropylene but it is also used in elastomeric cable compounds. Its main limitation is the tendency to agglomerate in polymers, affecting processability and performance.

Zinc borate is an effective and economical flame-retardant synergist of organic halogens in polymers. It has been demonstrated that the combination of zinc borate and ATH can be used as an effective flame retardant and smoke suppressant in halogen-free polymers such as EVA, polyethylene, EPDM, EEA, epoxy, and acrylics. Zinc borates have also found uses in PVC formulations. They have been shown to be effective flame/smoke suppressants when used as partial replacements for the antimony oxide that is normally used in a typical flexible PVC cable jacket, for example. For flexible vinyl and PVC plastisol formulations, a half to two-thirds of the antimony trioxide can be replaced by zinc borate without loss of flame retardancy.

Ultracarb (Manufactured by Microfine Minerals) is a naturally occurring mixture of two mineral fillers and is similar to ATH. However, the filler can be processed at higher temperatures and is less expensive. Ultracarb is based on a proprietary mixture of huntite, $Mg_3Ca(CO_3)_4$ and hydromagnesite $Mg_3(CO_3)3(OH)_2.3H_2O$. Ultracarb has been widely used in wire and cable applications in materials such as PVC, PE, EEA, PP, EPDM and EVA.

1.1.2.5.3 Phosphorus-containing Flame Retardants. These flame retardants mainly influence the reactions taking place in the condensed phase. They are particularly effective in materials with high oxygen content, such as oxygen-containing plastics as well as cellulose and its derivatives.

The range of phosphorus-containing flame retardants is extraordinarily versatile, since in contrast to halogen compounds, it extends over several oxidation states. Phosphates, phosphate esters, phosphonates, phosphine oxides, elemental red phosphorus are all used as flame retardants. Often the phosphorus compounds also contain halogens, which increase the effectiveness of the flame retardant (e.g., chlorophosphates and chlorophosphonates). The two most important categories are the phosphate esters, extensively used in flexible PVC, and chlorinated phosphates, commonly used in polyurethane formulations (Gachter and Muller 1993).

1.1.2.6 Lubricants

Lubricants are added to improve the ease of processing. A typical lubricant for wire and cable manufacturing is stearic acid (added to PVC). Lubricants help provide a consistent, flawless surface finish and make it possible to produce long lengths of wire at high line speed.

1.1.2.7 Colorants

Colorants are added to wire and cable resins for identification purposes. Vinyl wire and cable compounds can be manufactured in virtually any color. There are two major types of colorants – pigments and dyes. A pigment is insoluble and is dispersed as discrete particles throughout a resin to achieve a color. Pigments can be either organic or inorganic compounds. A dye is soluble in the resin and always an organic based material. Light stability is an important factor when selecting a colorant.

Pigments are typically identified by their color families and to some extent their properties. Common inorganic types include lead, cadmium, lead chromate, titanium dioxide, zinc sulfide, iron oxides, cadmium oxides, ultramarines, mixed metal oxides, and carbon black. Titanium dioxide and zinc sulfide are white pigments which can be used in most resins. Iron oxides come in red, yellow, brown, and black. Their heat stability varies and they can be used in a variety of resins. Lead chromates and lead chromate molybdates include bright yellows and oranges. Cadmium comes in reds, yellows, oranges and maroons and is excellent for engineering resins.

Chromium oxides are green and show very good heat and light fastness. Ultramarines come in blue, pink and violet shades and work in a wide range of resins. Alternatives to many of these "heavy metal" pigments are the "mixed-phase metal oxide" pigments (e.g., yellow nickel titanates and blue and green cobalt aluminates). Relatively new is a brilliant yellow bismuth vanadate. Orange version compounds have been developed as well. Cerium sulfide now is under commercialization for a range of reds. Organic pigments are also available in a wide range of colors. They, however, are more difficult to disperse than inorganic, which leads to possible loss in mechanical strength. The amount of colorants used in coated wire and cable is small and this makes it less of a priority for developing alternatives.

1.2 Presentation of Cable Types

As can be seen in Figure 1.3 many different cable types are in use all over the world. In this section of the study, major types of cables are presented and defined to show their major components, places of use, and their differences from each other.

Figure 1.3 The cross sections of various cable types

1.2.1 Telecomunication Cables

1.2.1.1 Telephone Cables

These cables with copper conductor used in local telephone network is produced in are used as telephone cables at indoor installations.

1.2.1.1.1 Fields of Applications. These cables are used for:

- telephone cables at indoor installations,
- telephone cables at outdoor installations,
- fire alarm systems communications at indoor stable installations,
- telephone cable at outdoor installations, between pillars in aerial ares and underground distribution.

1.2.1.1.2 Cable Constructions.

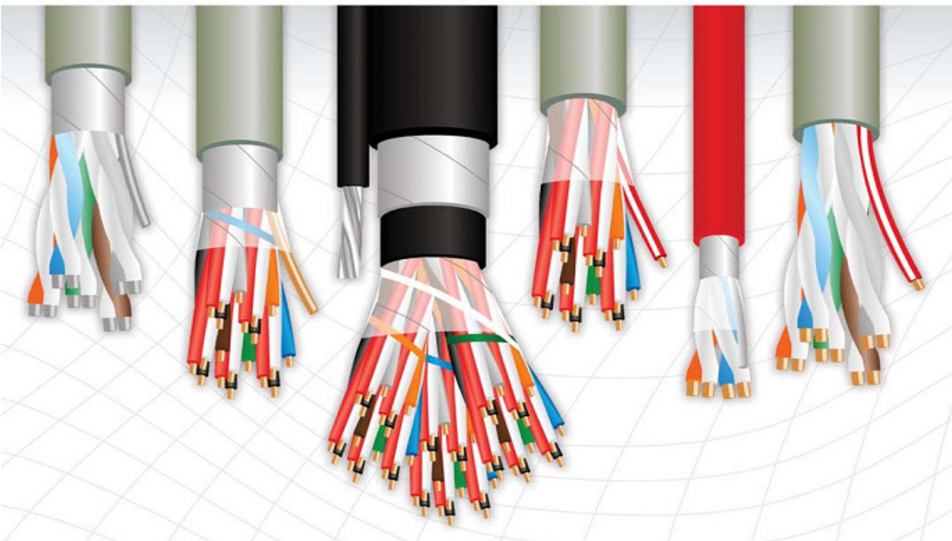
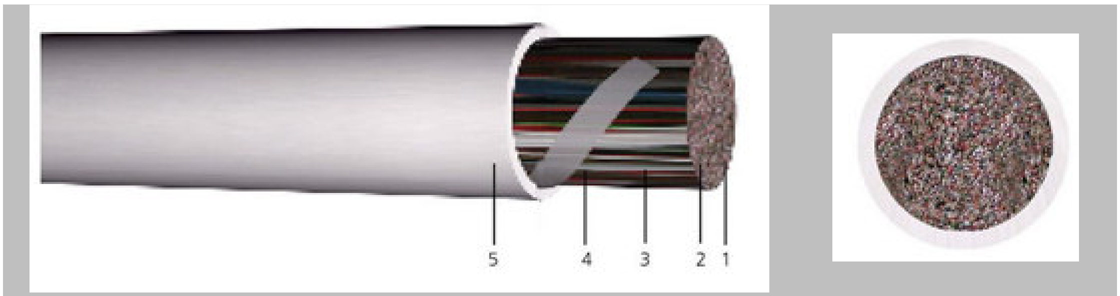
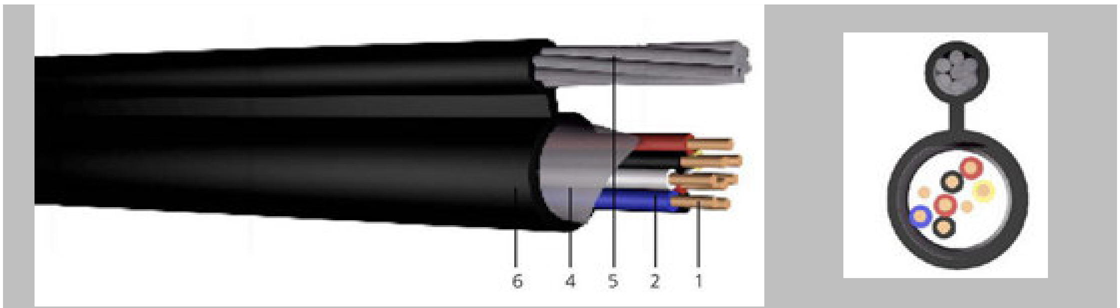


Figure 1.4 Telephone cable types



1. Conductor.
2. Insulation
3. Cable assembly
4. Core covering
5. Outer jacket
6. Identification tape
7. Length marking

Figure 1.5 One of the Telephone cable types



1. Conductor.
2. Insulation
3. Cable assembly
4. Core Covering
5. Messenger
6. Outer jacket
7. Identification tape
8. Length marking

Figure 1.6 One of the Telephone cable types

1.2.1.2 LAN&Data Cables

1.2.1.2.1 Fields of Applications. These cables are used for:

- data transfer,
- otomation systems,
- otomation systems in computer and office machines,
- otomation in fabric scada systems in fuel oil foundation,
- connections in data transmission systems.

1.2.1.2.2 Cable Constructions.

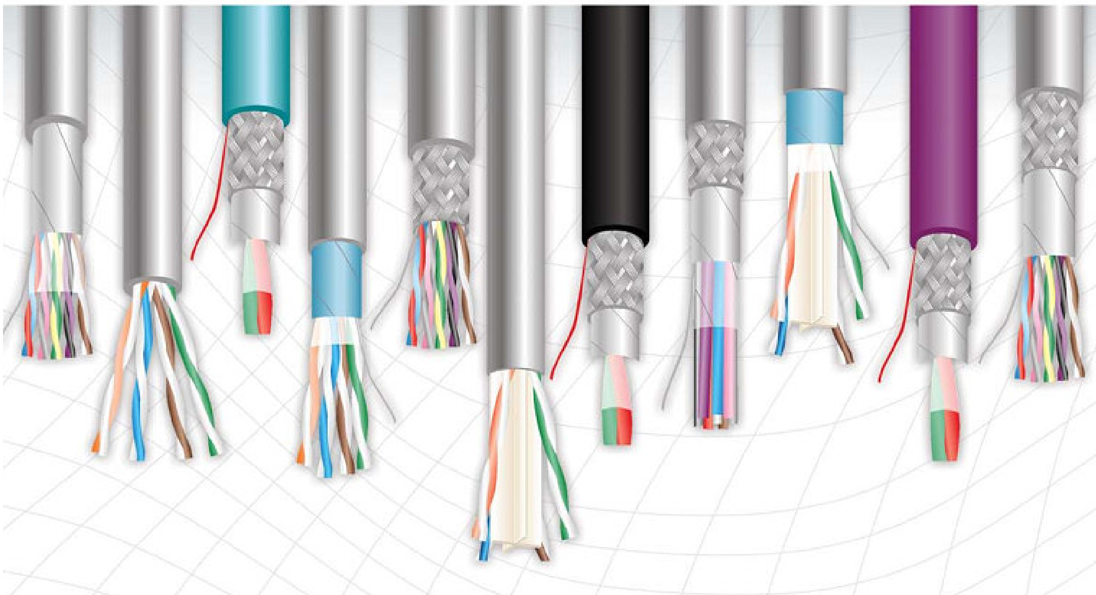


Figure 1.7 Lan&Data cable types

1.2.1.3 Fiber Optic Cables

1.2.1.3.1 Fields of Applications. Data transmission over optical fiber has greatly increased over the last few years, although fiber to the desktop has not really caught on as expected. However, fiber optic plays an important role in many networks. In addition, it has some outstanding advantages over copper cabling for certain applications.

When used as a link in a star bus topology, multi-mode fiber optic cable can transmit a maximum distance of 2,000 meters between all data closets, using a less expensive LED light source. While single mode fiber can transmit up to 3,000 meters, it requires a more expensive laser light source. By using fiber optic to link closets, it is possible to greatly extend the distance limitations in Ethernet networks using twisted pair only. Fiber optic is an outstanding choice for linking buildings together. In addition to the much greater distances possible, it is completely immune to over currents from lightning strikes and to ground potential problems. There is literally nothing metallic in a fiber optic cable to conduct current. All copper cabling radiates a signal to a certain degree, making it at least possible for someone with sophisticated enough equipment to electronically eavesdrop. Fiber optic cable radiates no electrical signal at all, and the cable would be down for quite some time if someone tried to splice into it.

Advantages

- Very high speed
- Very low attenuation
- Completely immune to EMI/RFI, over current, lightning strike
- Cannot electronically eavesdrop

Disadvantages

- Most expensive type of cable
- Most difficult type of cable to install
- Network hardware more expensive

Choosing the correct type of cabling depends on what type of network you have or intend to have, the number of network devices used, expected future growth, the speed requirements of your applications and the physical layout of your facility.

1.2.1.3.2 Cable Constructions. Fiber optic cable is composed of very thin, very pure strands of glass which utilize light beams to transmit data over long distances. Fiber optics can transmit greater amounts of information at a faster rate of speed than any other technology existing today. Not only is fiber the most secure means to communicate data, there doesn’t appear to be a known capacity or limit to the rate at which data can be transmitted.

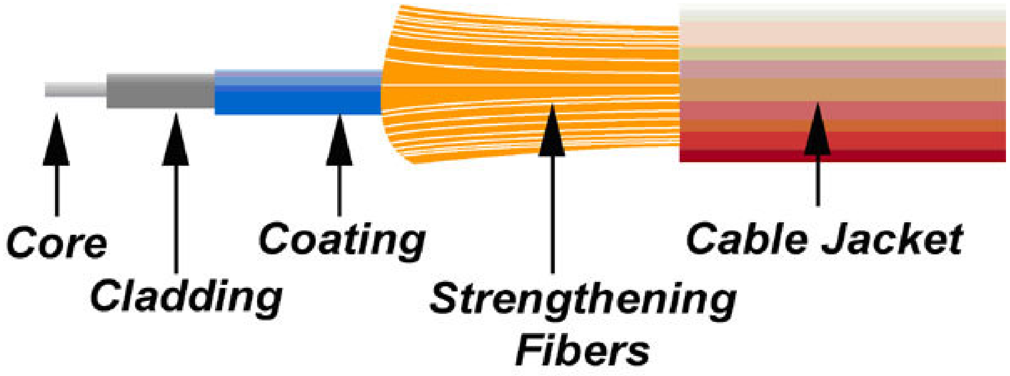


Figure 1.8 Fiber Optics Construction

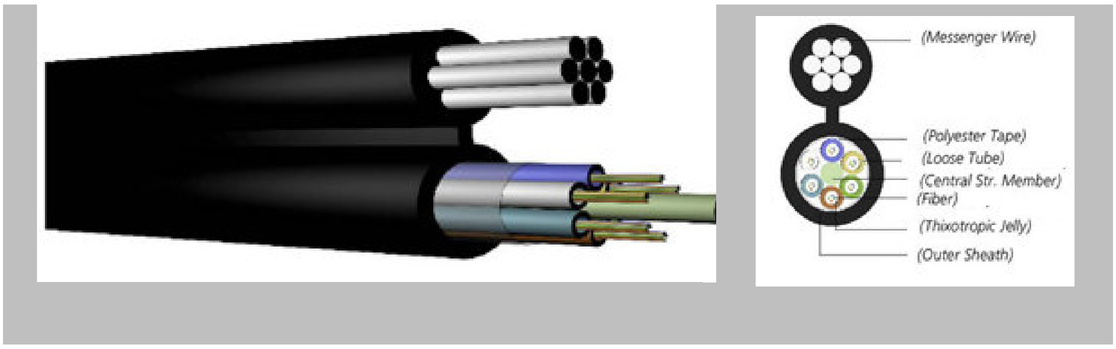


Figure 1.9 One of the Fiber Optic cable types

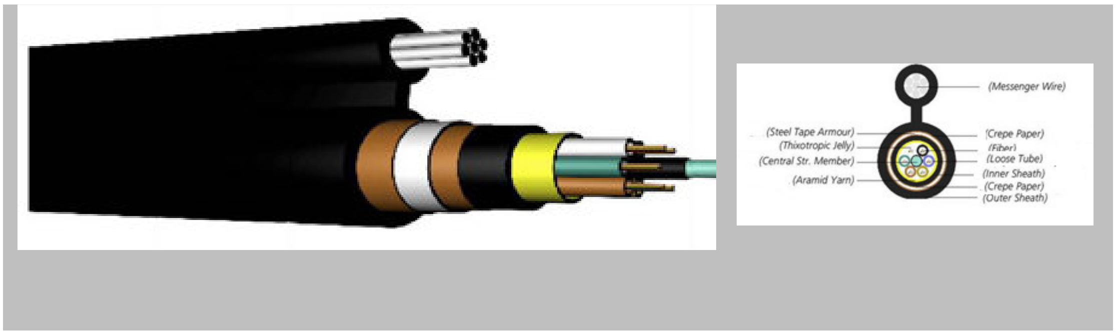


Figure 1.10 One of the Fiber Optic cable types

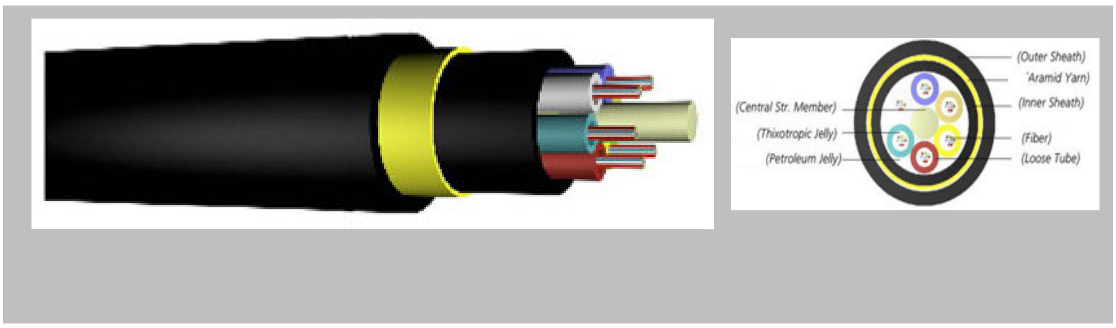


Figure 1.11 One of the Fiber Optic cable types

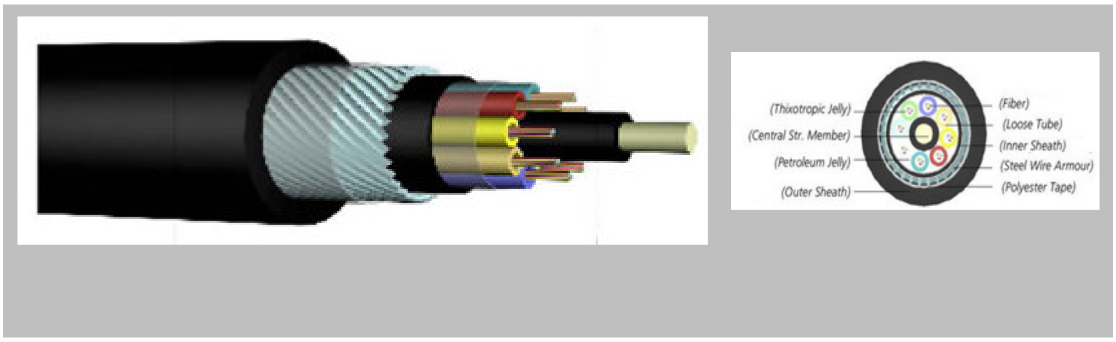


Figure 1.12 One of the Fiber Optic cable types

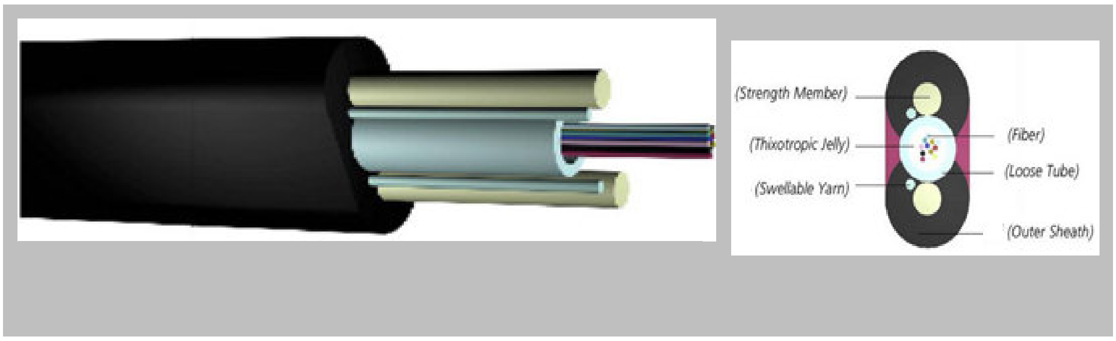


Figure 1.13 One of the Fiber Optic cable types

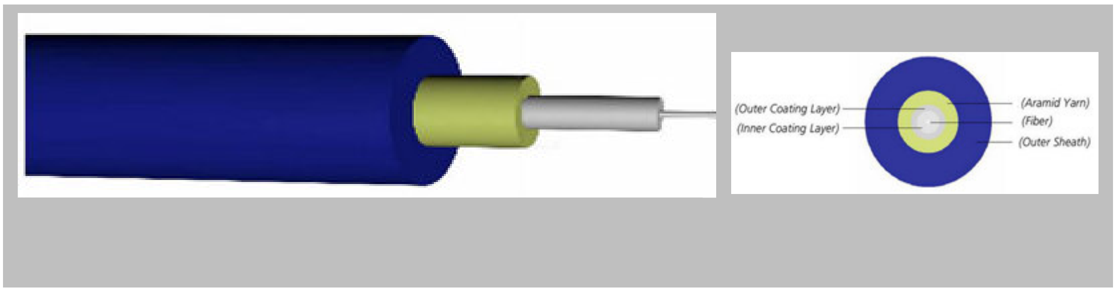


Figure 1.14 One of the Fiber Optic cable types

1.2.1.4 Signal&Control Cables

1.2.1.4.1 Fields of Applications. For fixed installation in open air in tray, trough and conduit or for direct burial in free draining soil or inside duct. General purpose control cable for control circuits in industrial plants, power stations and substations. Suitable for the operation and interconnection of protective break devices with heavy magnetic trip where inductively induced over voltages may occur. For systems operating at not more than 0.6 kV between a conductor to earth or 1 kV between conductors at maximum conductor temperatures of 90 °C for continuous normal operation and 250 °C for short circuit.

1.2.1.4.2 Cable Constructions.

Figure 1.15 Signal&Control cable types

1.2.1.5 Coaxial Cables

1.2.1.5.1 Fields of Applications.

- These cables are used for distribution indoor cable tv and satallite antenna systems with their own low attenuation values and high frequency permeabilty.
- They are main line cables and used for indoor security, cable tv and satallite antenna systems with their own low attenuation values, high shielding factor and high frequency permeabilty.
- They are aerial main line cables and used for outdoor security cable tv and satallite antenna systems with their own low attenuation values and high frequency permeabilty.
- They are main line distribution cables and used for outdoor security cable tv and satallite antenna systems with their own low attenuation values and high frequency permeabilty.
- These cables are designed as composite and used for image, sound, power, alarm and reference signals conductivity of camera applications.

Coaxial cable is a cable type used to carry radio signals, video signals, measurement signals and data signals. Coaxial cables exists because we can't run open-wire line near metallic objects (such as ducting) or bury it. We trade signal loss for convenience and flexibility. Coaxial cable consists of an insulated ceter conductor which is covered with a shield. The signal is carried between the cable shield and the center conductor. This arrangement give quite good shielding agains noise from outside cable, keeps the signal well inside the cable and keeps cable characteristics stable.

Coaxial cables and systems connected to them are not ideal. There is always some signal radiating from coaxial cable. Hence, the outer conductor also functions as a shield to reduce coupling of the signal into adjacent wiring. More shield coverage means less radiation of energy (but it does not necessarily mean less signal attenuation).

Coaxial cable are typically characterized with the impedance and cable loss. The length has nothing to do with a coaxial cable impedance. Characteristic impedance is determined by the size and spacing of the conductors and the type of dielectric used between them. For ordinary coaxial cable used at reasonable frequency, the characteristic impedance depends on the dimensions of the inner and outer conductors. The characteristic impedance of a cable (Zo) is determined by the formula 138 log b/a, where b represents the inside diameter of the outer conductor (read: shield or braid), and a represents the outside diameter of the inner conductor.

Here is a quick overview of common coaxial cable impedances and their main uses:

- 50 ohms: 50 ohms coaxial cable is very widely used with radio transmitter applications. It is used here because it matches nicely to many common transmitter antenna types, can quite easily handle high transmitter power and is traditionally used in this type of applications (transmitters are generally matched to 50 ohms impedance). In addition to this 50 ohm coaxial cable can be found on coaxial Ethernet networks, electronics laboratory interconnection (for example high frequency oscilloscope probe cables) and high frequency digital applications (fe example ECL and PECL logic matches nicely to 50 ohms cable). Commonly used 50 Ohm constructions include RG-8 and RG-58.

- 60 Ohms: Europe chose 60 ohms for radio applications around 1950s. It was used in both transmitting applications and antenna networks. The use of this cable has been pretty much phased out, and nowdays RF system in Europe use either 50 ohms or 75 ohms cable depending on the application.
- 75 ohms: The characteristic impedance 75 ohms is an international standard, based on optimizing the design of long distance coaxial cables. 75 ohms video cable is the coaxial cable type widely used in video, audio and telecommunications applications. Generally all baseband video applications that use coaxial cable (both analogue and digital) are matched for 75 ohm impedance cable. Also RF video signal systems like antenna signal distribution networks in houses and cable TV systems are built from 75 ohms coaxial cable (those applications use very low loss cable types). In audio world digital audio (S/PDIF and coaxial AES/EBU) uses 75 ohms coaxial cable, as well as radio receiver connections at home and in car. In addition to this some telecom applications (for example some E1 links) use 75 ohms coaxial cable. 75 Ohms is the telecommunications standard, because in a dielectric filled line, somewhere around 77 Ohms gives the lowest loss. For 75 Ohm use common cables are RG-6, RG-11 and RG-59.
- 93 Ohms: This is not much used nowadays. 93 ohms was once used for short runs such as the connection between computers and their monitors because of low capacitance per foot which would reduce the loading on circuits and allow longer cable runs. In addition thsi was used in some digital commication systems (IBM 3270 terminal networks) and some early LAN systems.

The characteristic impedance of a coaxial cable is determined by the relation of outer conductor diameter to inner conductor diameter and by the dielectric constant of the insulation. The impednage of the coaxial cable chanes soemwhat with the frequency. Impedance changes with frequency until resitance is a minor effect and until dielectric dielectric constant is table. Where it levels out is the "characteristic impedance". The freqnency where the impedance matches to the characteristic impedance varies somwehat between different cables, but this generally happens at frequency range of around 100 kHz (can vary).

Essential properties of coaxial cables are their characteristic impedance and its regularity, their attenuation as well as their behaviour concerning the electrical separation of cable and environment, i.e. their screening efficiency. In applications where the cable is used to supply voltage for active components in the cabling system, the DC resistance has significance. Also the cable velocity information is needed on some applications. The coaxial cable velocity of propagation is defined by the velocity of the dielectric. It is expressed in percents of speed of light. Here is some data of come common coaxial cable insulation materials and their velocities:

Polyethylene (PE)	66%
Teflon	70%
Foam	78…86%

Return loss is one number which shows cable performance meaning how well it matches the nominal impedance. Poor cable return loss can show cable manufacturing defects and installation defects (cable damaged on installation). With a good quality coaxial cable in good condition you generally get better than -30 dB return loss, and you should generally not got much worse than -20 dB. Return loss is same thing as VSWR term used in radio world, only expressed differently (15 dB return loss = 1.43:1 VSWR, 23 dB return loss = 1.15:1 VSWR etc.).

1.2.1.5.2 Cable Constructions.

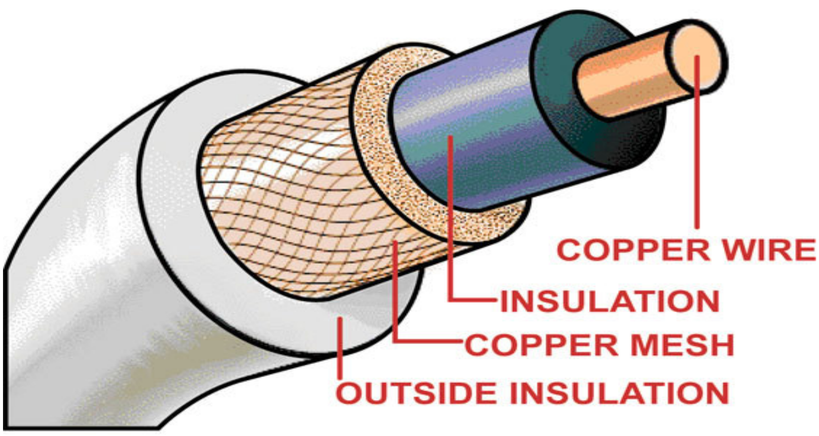


Figure 1.16 Construction of Coaxial Cable

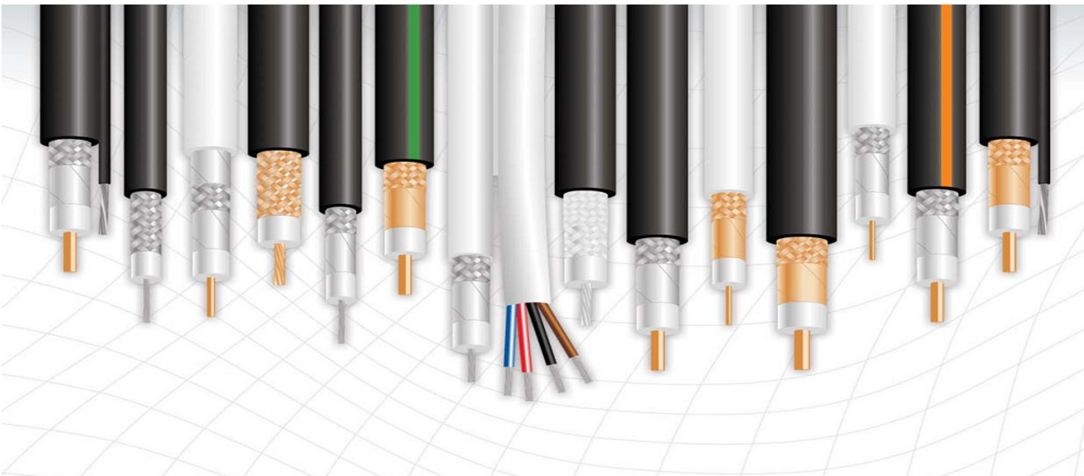


Figure 1.17 Coaxial Cable Types

A coaxial cable is one that consists of two conductors that share a common axis. The inner conductor is typically a straight wire, either solid or stranded and the outer conductor is typically a shield that might be braided or a foil.

The dielectric of a coaxial cable serves but one purpose - to maintain physical support and a constant spacing between the inner conductor and the outer shield. In terms of efficiency, there is no better dielectric material than air. In most practical cable companies use a variety of hydrocarbon-based materials such as polystyrene, polypropylenes, polyolefins and other synthetics to maintain structural integrity.

Sometimes coaxial cables are used also for carrying low frequency signals, like audio signals or measurement device signals. In audio applications especially the coaxial cable impedance does not matter much (it is a high frequency property of cable). Generally coaxial has a certain amount of capacitance (50 pF/foot is typical) and a certain amount of inductance. But it has very little resistance.

General characteristics of cables:

- A typical 50 ohm coaxial cable is pretty much 30pf per foot (doesn't apply to miniature cables or big transmitter cables, check a cable catalogue for more details). 50 ohms coaxial cables are used in most radio applications, in coaxial Ethernet and in many instrumentation applications.

- A typical 75 ohm coaxial cable is about 20 pf per foot (doesn't apply to miniature cables or big transmitter cables, check a cable catalogue for more details). 75 ohms cable is used for all video application (baseband video, monitor cables, antenna networks cable TV, CCTV etc.), for digital audio (S/PDIF, coaxial AES/EBU) and for telecommunication application (for example for E1 coaxial cabling).
- A typical 93 ohm is around 13 pf per foot (does not apply to special cables). This cable type is used for some special applications.

Please note that these are general statements. A specific 75 ohm cable could be 20pF/ft. Another 75 ohm cable could be 16pF/ft. There is no exact correlation between characteristic impedance and capacitance.

In general, a constant impedance (including connectors) cable, when terminated at both ends with the correct load, represents pure resistive loss. Thus, cale capacitance is immaterial for video and digital applications.

Typical coaxial cable constructions are:

- Flexible (Braided) Coaxial Cable is by far the most common type of closed transmission line because of its flexibility. It is a coaxial cable, meaning that both the signal and the ground conductors are on the same center axis. The outer conductor is made from fine braided wire, hence the name "braided coaxial cable". This type of cable is used in practically all applications requiring complete shielding of the center conductor. The effectiveness of the shielding depends upon the weave of the braid and the number of braid layers. One of the draw-backs of braided cable is that the shielding is not 100% effective, especially at higher frequencies. This is because the braided construction can permit small amounts of short wavelength (high frequency) energy to radiate. Normally this does not present a problem; however, if a higher degree of shielding is required, semirigid coaxial cable is recommended. In some high frequency flexible coaxial cables the outer shield consists if normal braids and an extra aluminium foil shield to give better high frequency shielding.

- Semirigid Coaxial Cable uses a solid tubular outer conductor, so that all the RF energy is contained within the cable. For applications using frequencies higher than 30 GHz a miniature semirigid cable is recommended.
- Ribbon Coaxial Cable combines the advantages of both ribbon cable and coaxial cable. Ribbon Coaxial Cable consists of many tiny coaxial cables placed physically on the side of each other to form a flat cable. Each individual coaxial cable consists of the signal conductor, dielectric, a foil shield and a drain wire which is in continuous contact with the foil. The entire assembly is then covered with an outer insulating jacket. The major advantage of this cable is the speed and ease with which it can be mass terminated with the insulation displacement technique.

Often you will hear the term shielded cable. This is very similar to coaxial cable except the spacing between center conductor and shield is not carefully controlled during manufacture, resulting in non-constant impedance.

If the cable impedance is critical enough to worry about correctly choosing between 50 and 75 Ohms, then the capacitance will not matter. The reason this is so is that the cable will be either load terminated or source terminated, or both, and the distributed capacitance of the cable combines with its distributed inductance to form its impedance.

A cable with a matched termination resistance at the other end appears in all respects resistive, no matter whether it is an inch long or a mile. The capacitance is not relevant except insofar as it affects the impedance, already accounted for. In fact, there is no electrical measurement you could make, at just the end of the cable, that could distinguish a 75 Ohm (ideal) cable with a 75 Ohm load on the far end from that same load without intervening cable. Given that the line is teminated with a proper 75 ohm load (and if it's not, it damn well should be!), the load is 75 ohms resistive, and the lumped capacitance of the cable is irrelevant. Same applies to other impedance cables also when terminated to their nominal impedance.

There exist an effect that characteristic impedance of a cable if changed with frequency. If this frequency-dependent change in impedance is large enough, the cable will be impedance-matched to the load and source at some frequencies, and mismatched at others. Characteristic impedance is not the only detail in cable. However there is another effect that can cause loss of detail fast-risetime signals. There is such a thing as frequency-dependent losses in the cable. There is also a property of controlled impedance cables known as dispersion, where different frequencies travel at slightly different velocities and with slightly different loss.

In some communications applications a pair of 50 ohm coaxial cables are used to transmit a differential signal on two non-interacting pieces of 50-ohm coax. The total voltage between the two coaxial conductors is double the single-ended voltage, but the net current in each is the same, so the differential impedance between two coax cable used in a differential configuration would be 100 ohms. As long as the signal paths don't interact, the differential impedance is always precisely twice the single-ended impedance of either path.

1.2.1.6 Instrument Cables

1.2.1.6.1 Fields of Applications. These cables are used for digital and analog signal communication of instrument and control systems in petrochemical, chemical and energy industries.

1.2.1.6.2 Cable Constructions.

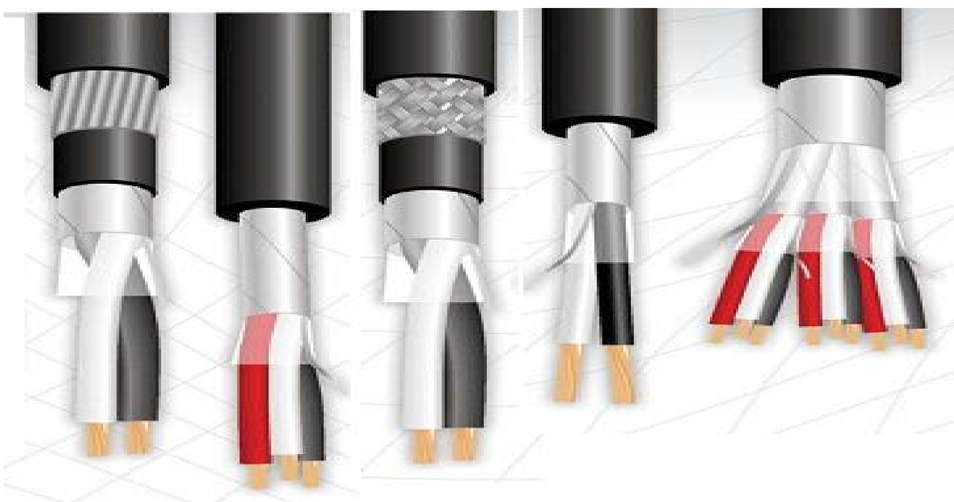


Figure 18. Construction of Instrument Cables

1.2.1.7 Audio&Video Cables

1.2.1.7.1 Fields of Applications. These cables are used;

- in stable and stage systems for instrument connection of Professional sound systems,
- in professional sound system for stable and flexing installations,
- inside of rack, Professional sound system montages and stable installations,
- for distance connection in professional and amateur sound systems,
- for connection of many sound signals in stage and stable Professional sound systems,
- for stage and stable professional sound systems,
- for high quality SDI and HDTV video signal carrying with low attenuation values and for video signal transfer in television studio systems and digital studio places,
- for high quality SDI and HDTV video signal carrying,
- for high quality SVGA and component video signal carrying approved to VGA video connections which have many pins.

1.2.1.7.2 Cable Constructions

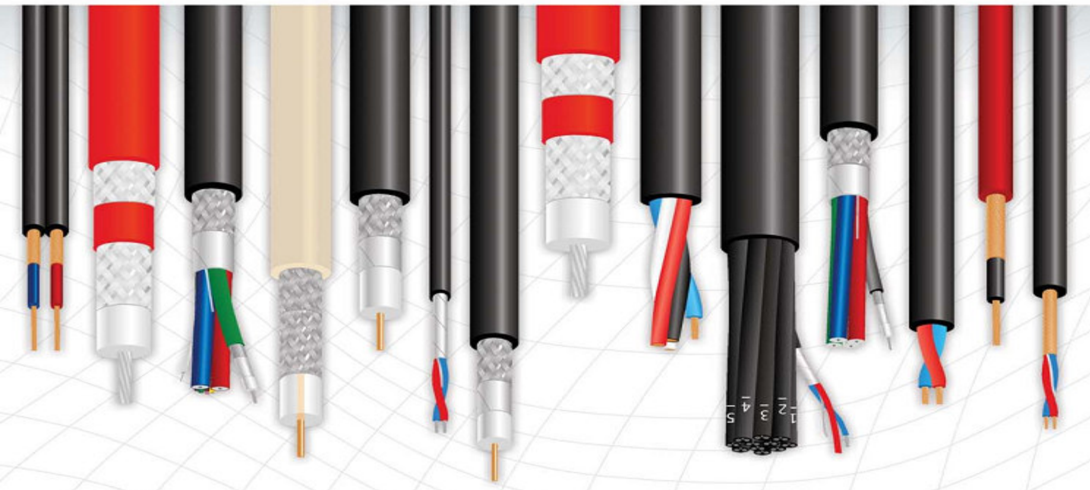


Figure 1.19 Construction of Audio&Video Cables

1.2.2 Energy Cables

1.2.2.1 Installation Cables

1.2.2.1.1 Fields of Applications. For fixed installation in dry, damp or wet premises of single phase and three phase wiring systems operating at not more than 300 V between phase to earth or 500 V phase to phase. At maximum conductor temperatures of 70 °C for continuous normal operation and 160 °C for short circuit. May be installed on, in or under plaster or enclosed in a metallic or non-metallic conduit, ducting or trunking. Also for outdoor sun-protected installation. Unsuitable for direct underground or in water laying.

These cables are used ;

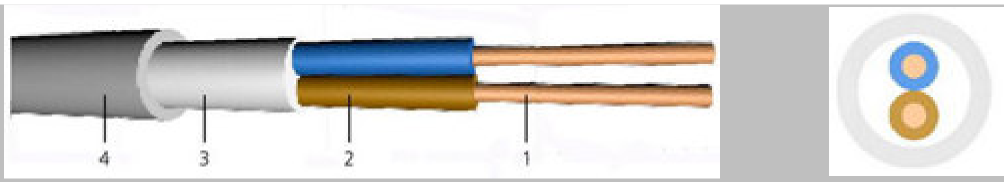
- in dry rooms,
- switch and distribution boards, for laying in conduit on and under plaster and on insulating supports above plaster.

1.2.2.1.2 Cable Constructions. This specification describes PVC insulated, PVC sheathed circular single, twin, 3-core, 4-core and 5-core cables for fixed wiring in domestic, commercial and industrial buildings. They are intended for use on single phase and three phase installations not exceeding 500 Volt phase to phase at maximum conductor temperatures of 70 °C for continuous normal operation and 160 °C for short circuit maximum conductor temperature.

- Directly over the conductor shall be applied a homogeneous wall of PVC insulation. The average thickness shall be not less than the given in the attached table.

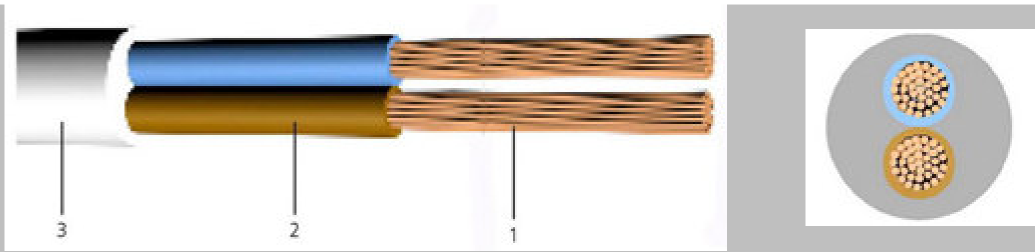
1. Solid or stranded copper conductor 2. PVC insulation.

Figure 1.20 One of the Installation Cable type



1. Solid or stranded copper conductor.
2. PVC insulation.
3. PVC filler.
4. PVC outer sheath.

Figure 1.21 One of the Installation Cable type



1. Fine stranded copper conductor.
2. PVC insulation.
3. PVC outer sheath.

Figure 1.22 One of the Installation Cable type

1.2.2.2 Low Voltage Cables

1.2.2.2.1 Fields of Applications. These cables are used;

- indoors and outdoors,
- in cable ducts,
- underground,
- in power or switching stations,
- local energy distributions,
- in industrial plants where there is no risk of mechanical damage.

1.2.2.2.2 Cable Constructions

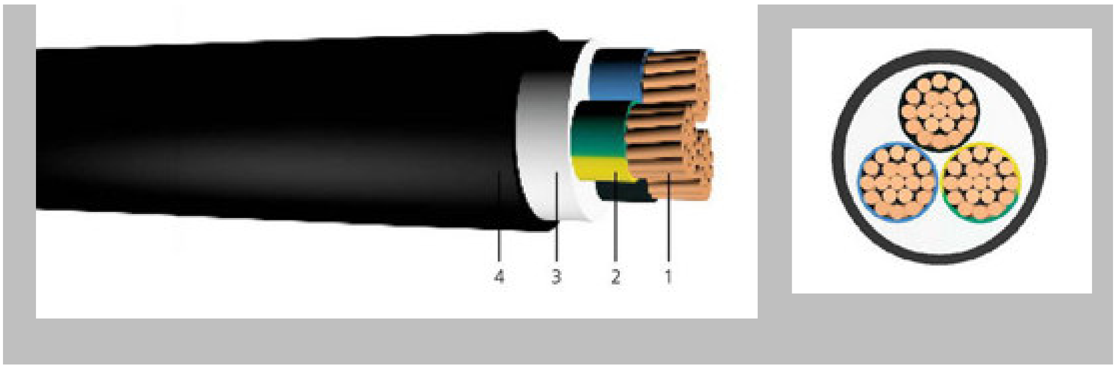


Figure 1.23 One of the Low Voltage Cable type

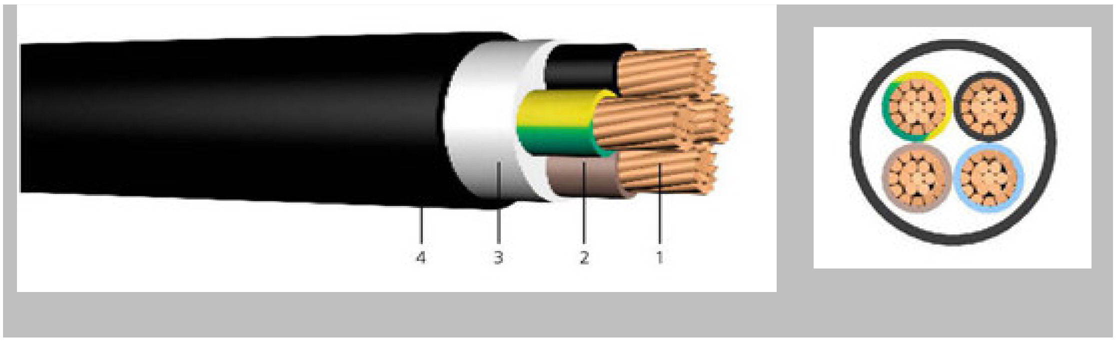
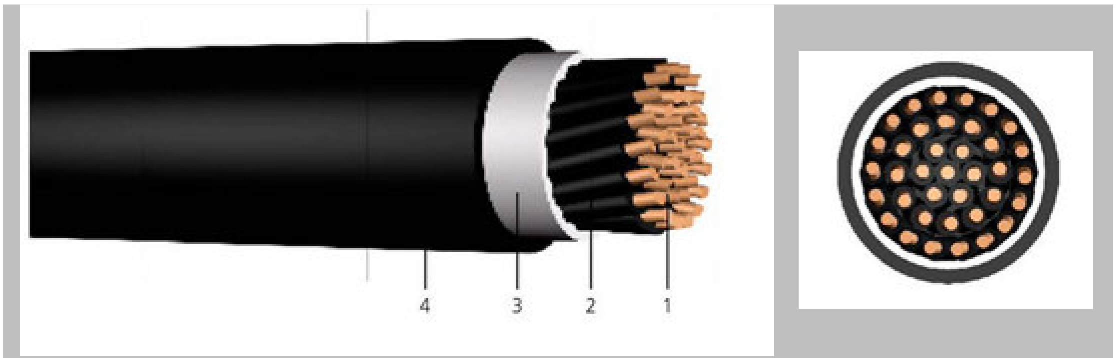


Figure 1.24 One of the Low Voltage Cable type



1. Solid or stranded copper conductor.
2. PVC insulation.
3. Filler.
4. PVC outer sheath.

Figure 1.25 One of the Low Voltage Cable type

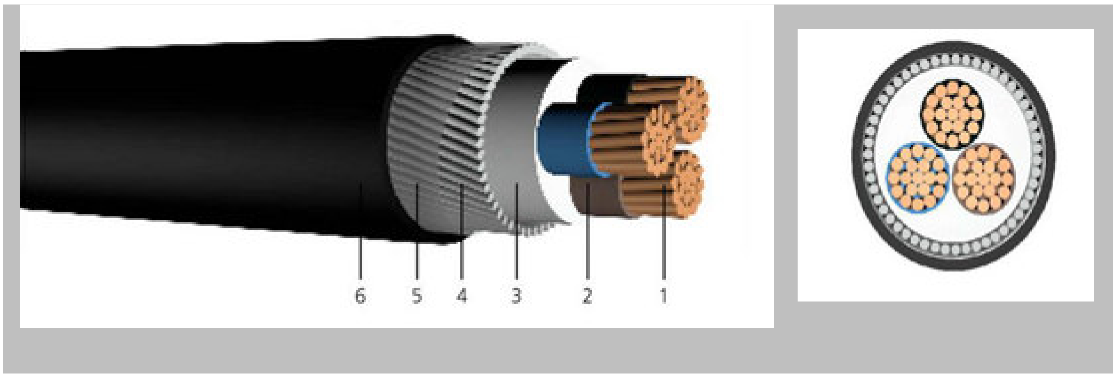
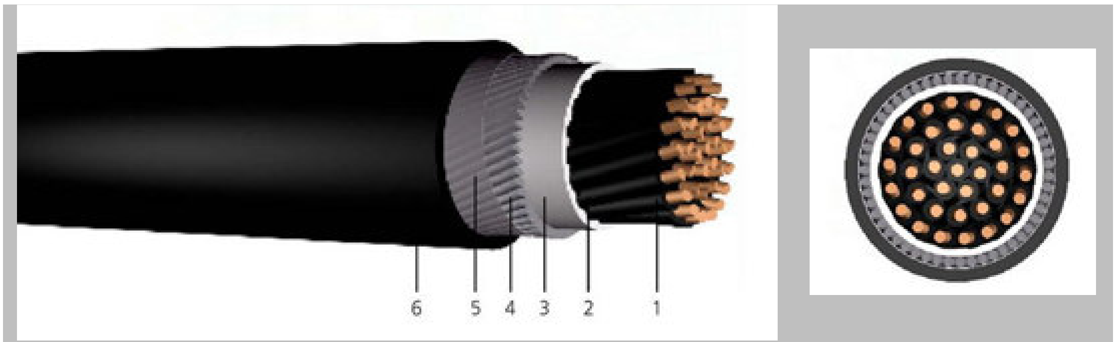
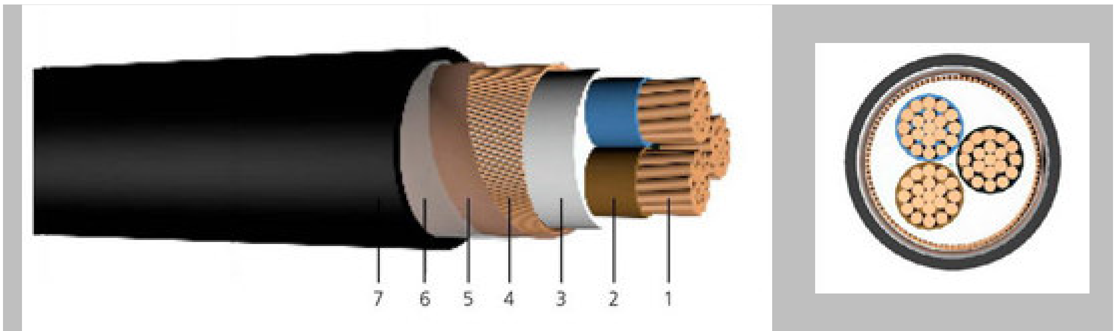


Figure 1.26 One of the Low Voltage Cable type



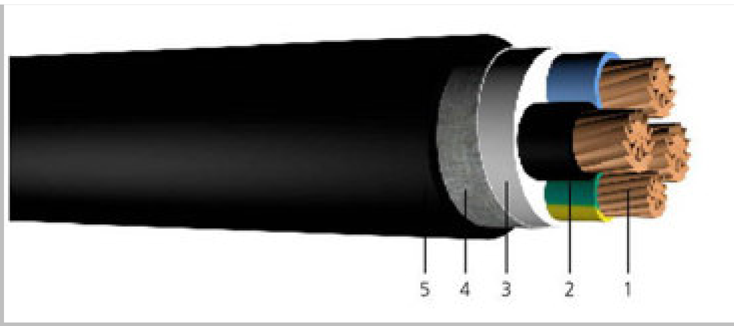
1. Solid or stranded copper conductor.
2. PVC insulation.
3. Filler.
4. Galvanized round steel wires.
5. Polyester tape.
6. PVC outer sheath.

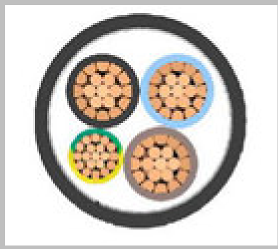
Figure 1.27 One of the Low Voltage Cable type



1. Solid or stranded copper conductor.
2. PVC insulation.
3. Filler.
4. Concentric screen.
5. Copper tape as binder.
6. Polyester tape.
7. PVC outer sheath.

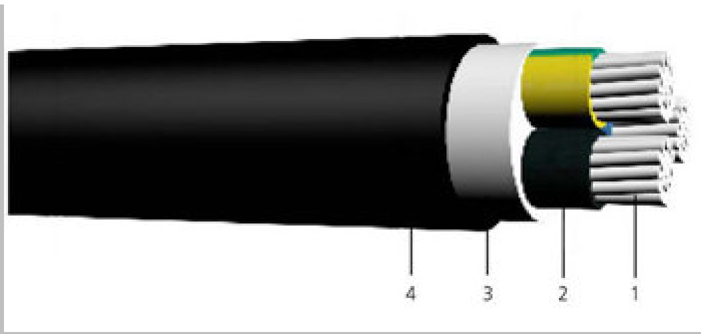
Figure 1.28 One of the Low Voltage Cable type

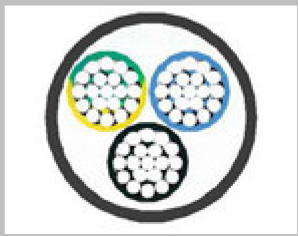




1. Stranded copper conductor.
2. PVC insulation.
3. Filler.
4. Galvanized doubled steel tape armoured.
5. PVC outer sheath.

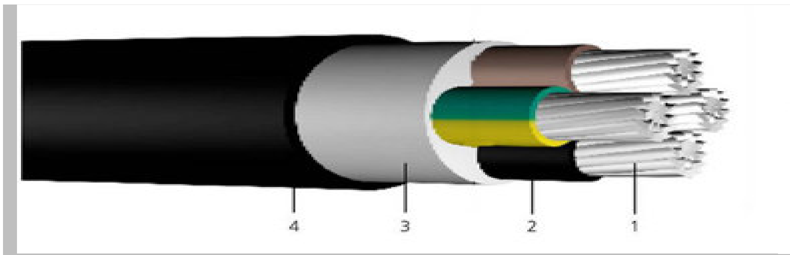
Figure 1.29 One of the Low Voltage Cable type





1. Stranded aluminium conductor.
2. PVC insulation.
3. Filler.
4. PVC outer sheath.

Figure 1.30 One of the Low Voltage Cable type



1. Stranded aluminium conductor.
2. PVC insulation.
3. Filler.
4. PVC outer sheath.

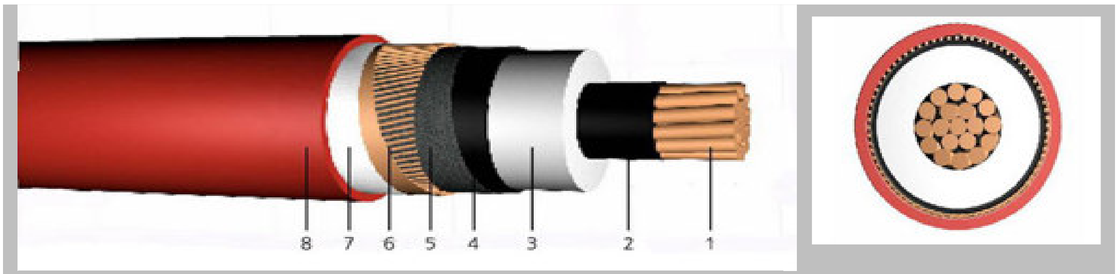
Figure 1.31 One of the Low Voltage Cable type

1.2.2.3 Medium Voltage Cables

1.2.2.3.1 Fields of Applications. These cables are used;

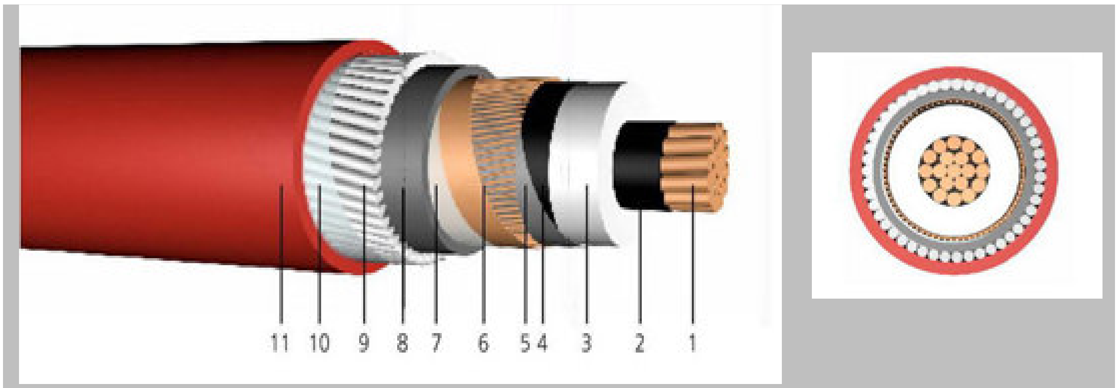
- in energy networks with sudden load changes.
- in residental or industrial areas, underground or in ducts.
- If the cable gets water inside due to the mechanical damagesi swellable tapes prevent the movement of the water inside the cable.
- And these are cables with low dielectric loses.

1.2.2.3.2 Cable Constructions



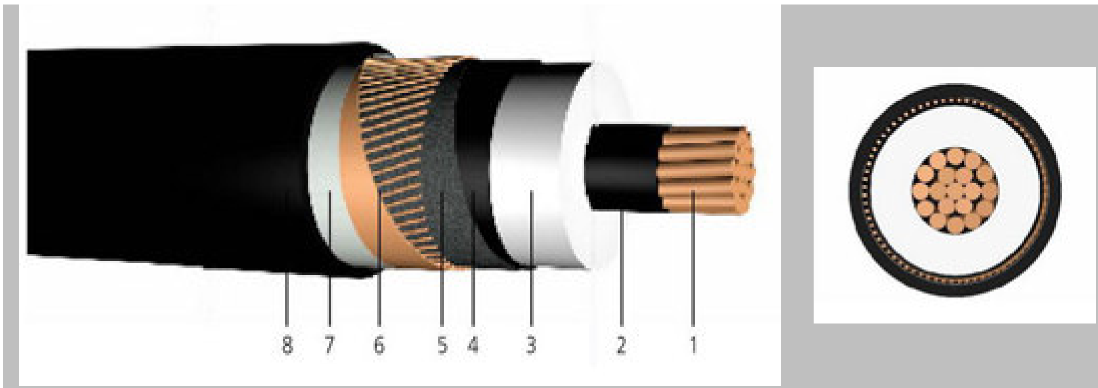
1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Copper wire screen
6. Polyester tape
7. PVC outer jacket

Figure 1.32 One of the Medium Voltage Cable type



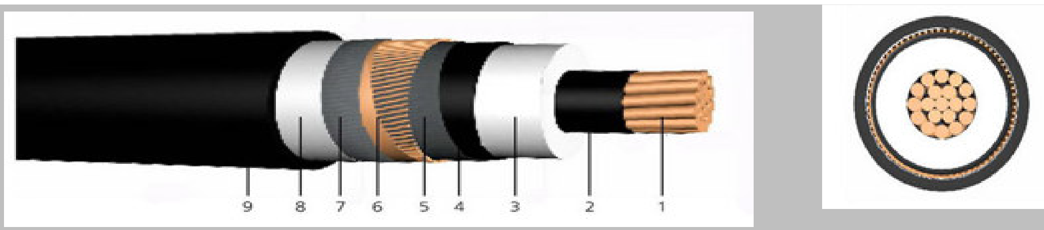
1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. PVC outer jacket
7. Copper wire screen
8. Polyester tape
9. Seperation sheath
10. Aluminium wire armour
11. Polyester tape

Figure 1.33 One of the Medium Voltage Cable type



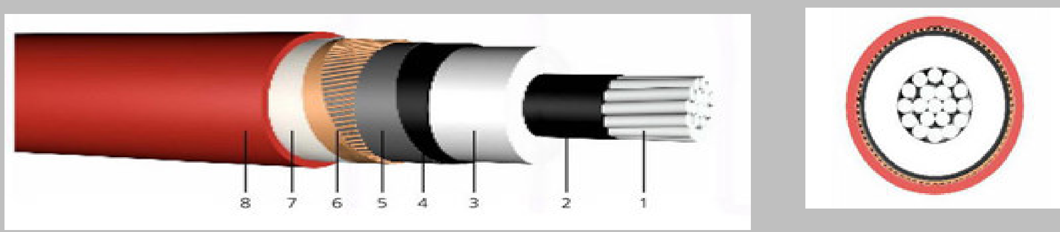
1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive swellable tape
6. Copper wire screen
7. Swellable tape
8. PE outer jacket

Figure 1.34 One of the Medium Voltage Cable type



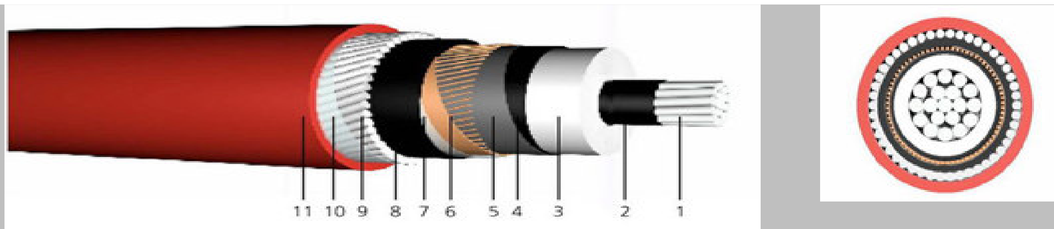
1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Swellable tape
6. Copper wire screen
7. Swellable tape
8. PE coated aluminium tape
9. PE outer jacket

Figure 1.35 One of the Medium Voltage Cable type



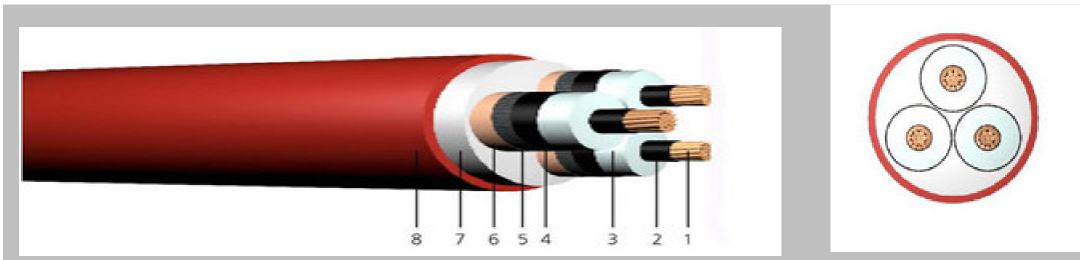
1. Stranded aluminium conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. Copper wire screen
7. Polyester tape
8. PVC outer jacket

Figure 1.36 One of the Medium Voltage Cable type



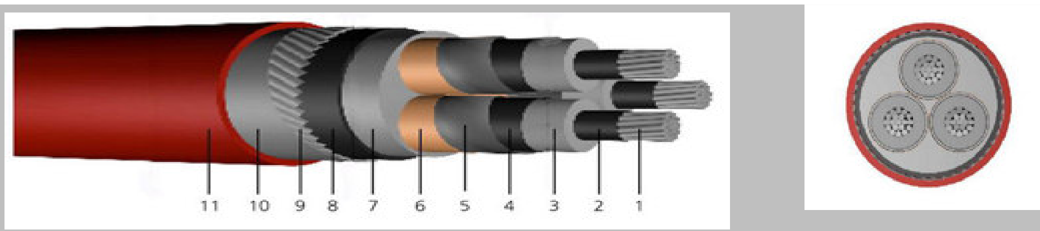
1. Stranded aluminium conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. Copper wire screen
7. Polyester tape
8. Seperation sheath
9. Aluminium wire armour
10. Polyester tape
11. PVC outer jacket

Figure 1.37 One of the Medium Voltage Cable type



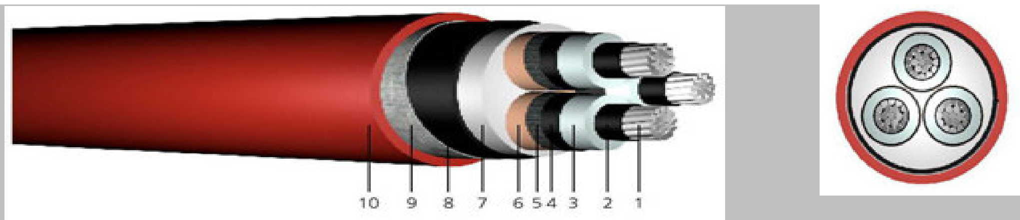
1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. Copper tape screen
7. Filler
8. PVC outer jacket

Figure 1.38 One of the Medium Voltage Cable type



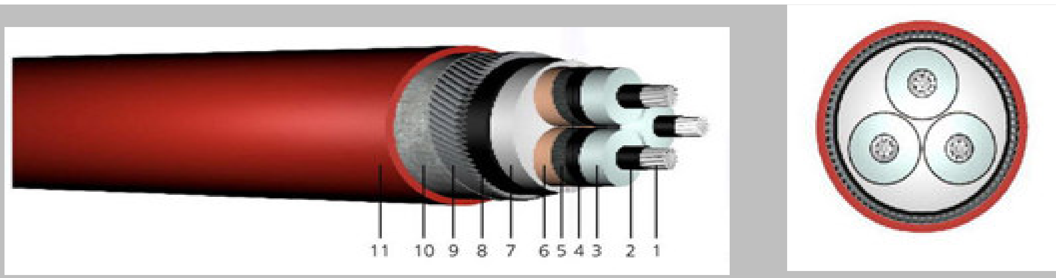
1. Stranded aluminium conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. Copper tape screen
7. Filler
8. PVC inner jacket
9. Galvanized flat steel wire armouring
10. Galvanized steel tape
11. PVC outer jacket

Figure 1.39 One of the Medium Voltage Cable type



1. Stranded aluminium conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. Copper tape screen
7. Filler
8. PVC inner jacket
9. Galvanized double steel tape
10. PVC outer jacket

Figure 1.40 One of the Medium Voltage Cable type



1. Stranded aluminium conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive tape
6. Copper tape screen
7. Filler
8. PVC iner jacket
9. Galvanized round steel wire
10. Galvanized steel tape
11. PVC outer jacket

Figure 1.41 One of the Medium Voltage Cable type

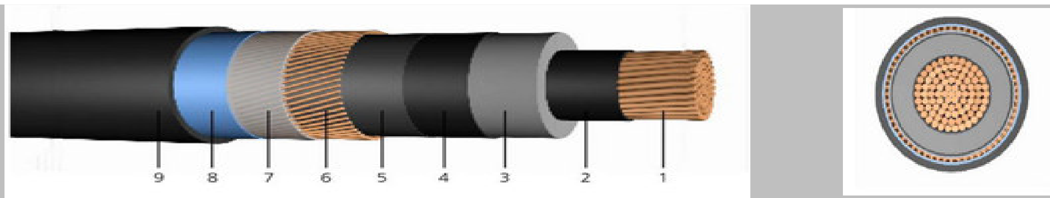
1.2.2.4 High Voltage Cables

1.2.2.4.1 Fields of Applications. These cables are used;

- in residential or industrial areas, underground or in ducts.

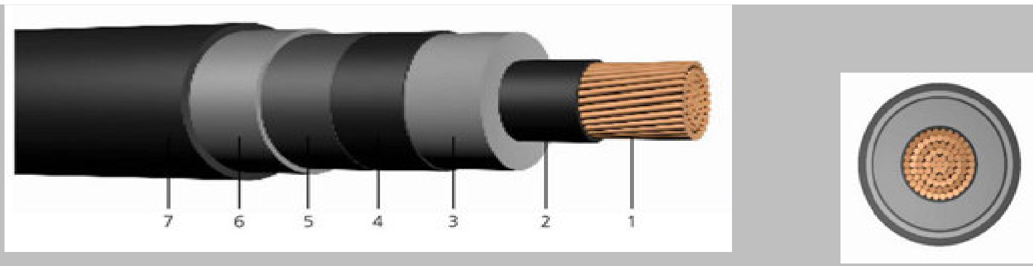
- If the cables gets water inside due to the mechanical damages, swellable tapes prevent the movement of the water inside the cable.

1.2.2.4.2 Cable Constructions



1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive swelible tape
6. Copper wire screen
7. Swelible tape
8. Aluminium tape
9. PE outer jacket

Figure 1.42 One of the High Voltage Cable type



1. Stranded copper conductor.
2. Inner semi-conductive layer
3. XLPE insulation
4. Outer semi-conductive layer
5. Semi-conductive swelible tape
6. Lead shealth
7. PE outer jacket

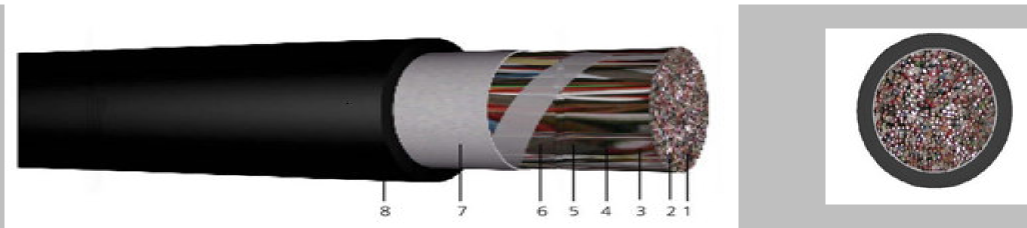
Figure 1.43 One of the High Voltage Cable type

1.2.2.5 Underground Cables

1.2.2.5.1 Fields of Applications. Underground cables can normally be identified by the heavy armouring. Lead and steel covered as underground cables are they put up a tough job for the separaton process.

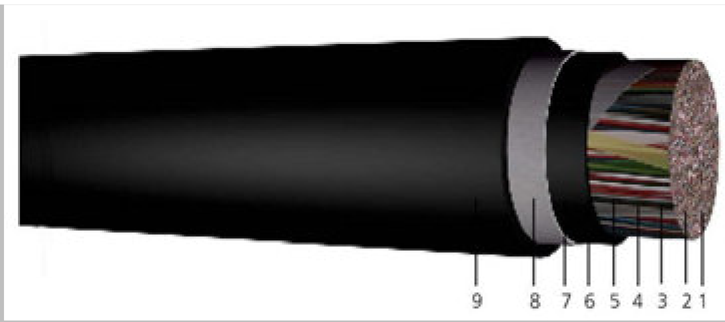
Underground cables also consists of a considerable amount of grease, plastics, paper and of course lead ánd copper. What makes this job so special is that the substantial amount of grease actually makes all the material stick together including all the metals.

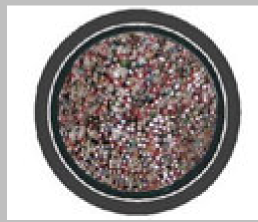
1.2.2.5.2 Cable Constructions



1. Conductor.
2. Insulation
3. Cable assembly
4. Filling compound
5. Core covering
6. Flooding compound
7. Shield
8. Outer jacket
9. Identification tape
10. Length marking

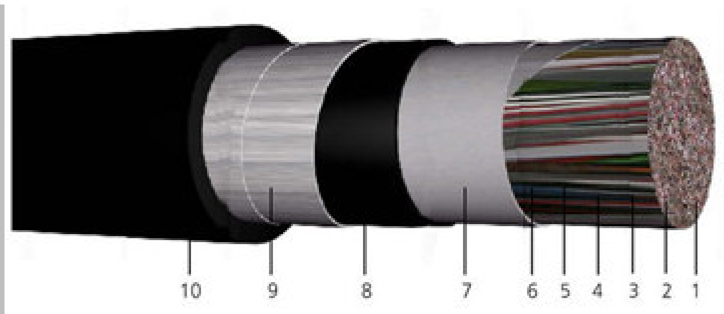
Figure 1.44 One of the Underground Cable type





1. Conductor.
2. Insulation
3. Cable assembly
4. Filling compound
5. Core covering
6. Innet jacket
7. Flooding compound
8. Shield
9. Jacket
10. Identification tape
11. Length marking

Figure 1.45 One of the Underground Cable type



1. Conductor.
2. Insulation
3. Cable assembly
4. Filling compound
5. Core covering
6. Flooding compound
7. Shield
8. Inner jacket
9. Armour
10. Jacket
11. Identification tape
12. Length marking

Figure 1.46 One of the Underground Cable type

1.2.3 Special Cables

1.2.3.1 Halogen Free Cables

1.2.3.1.1 Fields of Applications. Halogens are the elements as flourine, chlorine, bromine and iodine. The are the most widely used raw materials for the PVC insulation cable and sheathing raw material. The main reason that make them so widely use are their low prices. PVC(Polyvinylchloride) is not halogenfree material that has a chloride in its molecular structure. In the case of a fire the cabl insulation and the outer sheath material easily burn and the fire progres rapidly. It causes the release of toxic and corrosive gases during the fire. The released chlorine atoms composite themselves with hydrogen which is decomposed from plastic material as well as with hydrochloric acid from the existing air which in turn causes events with the resulting deads of humans and animals in the indoor environments. As for the corrosive gases they cause to wear, rust and deteriorate of the surface of metals. The density of smoke is increased because it releases black and dark smoke. The increase of density is in turn prevents the fire extinguishing works while everwhere is covered with a dark, black smoke. Halogenfree compounds are used in order to overcome the mentioned disadvantages of PVC. These compounds contain considerable percentage of flame protective materials. These halogenfree materials are composed with polymers on the basis of pure hydrocarbons used as the insulation and sheath materials of cables. By burning such kind of materials produce no corrosive and toxic gases but only water vapour and carbondioxide. Halogenfree cables are hardly flammable and self extinquishing. They do not release dark and black smoke. They have such protective materials for example of an aluminium hydroxide which on one side cools the fire location by setting free of crystal water and on the other side the released water vapour hinders the admittance of oxygen and thereby this suffocates the flame. By using of additional supporting tapes and filling yarns of glass web, mica and similar materials the funtionality for example of E 90 can be realized with the suitable cable accessories. The application of halogenfree cables are specified more and more with increasing numbers for the building where people gather where safety conciousness to protect the human life and valuable materials take a special significance.

The application areas of halogenfree are shortly as follows :

- Shopping malls,
- High buildings,
- Tunnels,
- Refineries mines power plants business centers,
- Museum,
- Data processing centers,
- Concert halls and densely populated places where high risk of loss of human life and property due to fire,
- Hospitals,
- airports,
- in multi story buildings,
- hotels, theatres, cinemas, schools etc.
- Fire warning plants, alarm systems, ventilation systems, escalators, lifts, safety lights, maintenance equipment.
- Underground railways and other railway plants
- Data processing installations
- Power stations and industrial plants with high valuable machines and materials or risky potentials
- Mining Works Shipbuilding and offshore plants
- Emergency power supply Works

The summary features of the halogenfree cables are as foollows:

- Flame retardant and difficult to burn so no flame propagation in case of fire can be resulted.
- Halogenfree, no evolution of corrosive gases.
- During the course of a fire the halogenfree cables emit low smoke.
- The risk of poisonous gases the danger of toxic gases caused by fire is far inferior Low caloric load Remarkable longer electrical functionality and flame influence.

Table 1.7 Halogen Free Cable Diameter and Light Transmission.

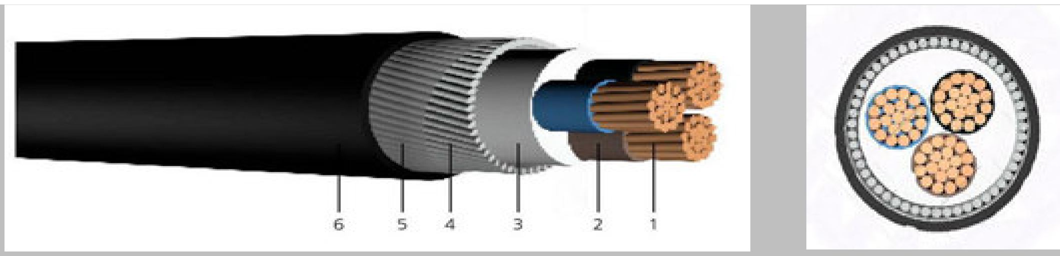
Cable Diameter	Light Transmission
>3-5 mm	40%
>5-10 mm	50%
>10-20 mm	60%
>20-40 mm	60%
>40 mm	70%

The dance black smoke which contains the toxic gas and substances is seen when PVC insulated cables are burned. These toxic and corrosive gases are very harmful to human life as to electronic devices around.The dense smoke which is a very important risk factor and danger human life during fire, can completely eliminate Access to escape routes and prevent fire fighters.

Last decade with the improved environmental consciousness and technological development s it is now possible to manufacture new and beter materials which replaces PVC insulation in cable industry.

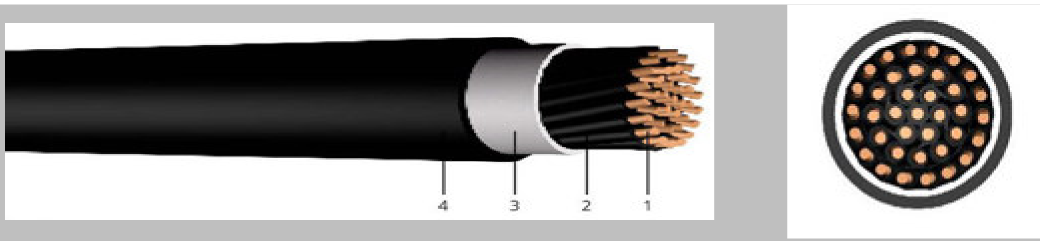
1.2.3.1.2 Cable Constructions.

Figure 1.47 Cable construction of the Underground Cable



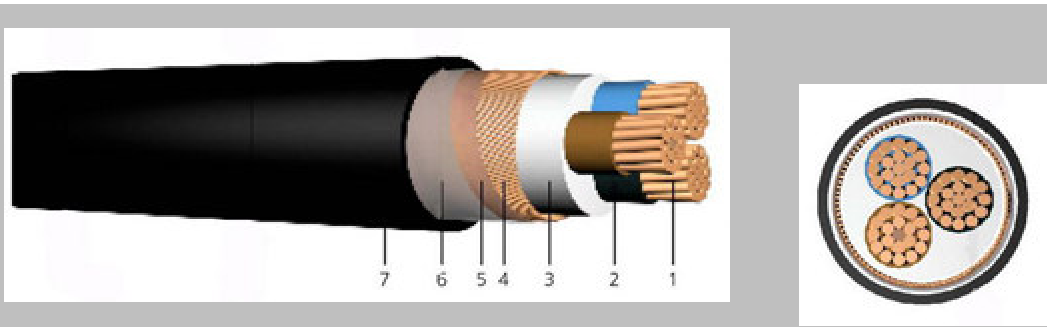
1. Solid or stranded copper conductor.
2. XLPE insulation.
3. HFFR iner sheath
4. Galvanized round steel wires
5. Polyester tape
6. HFFR outer sheath.

Figure 1.48 One of the Halogen Free Cable type



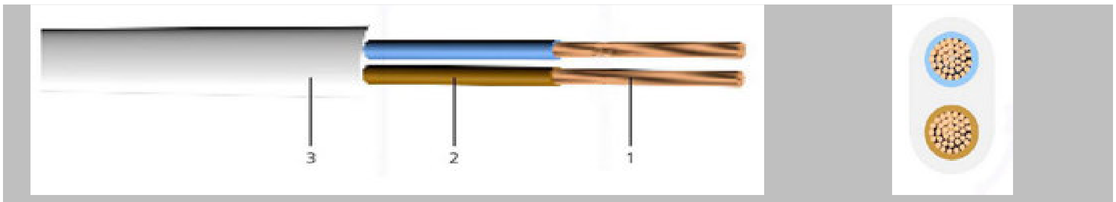
1. Solid or stranded copper conductor.
2. XLPE insulation.
3. HFFR filler
4. HFFR outer sheath.

Figure 1.49 One of the Halogen Free Cable type



1. Solid or stranded copper conductor.
2. XLPE insulation.
3. HFFR filler
4. Concentric screen
5. Copper tape as binder
6. Polyester tape
7. HFFR outer sheath.

Figure 1.50 One of the Halogen Free Cable type



1. Flexible copper conductor.
2. HFFR insulation.
3. HFFR outer sheath.

Figure 1.51 One of the Halogen Free Cable type

1.2.3.2 Silicon Cables

1.2.3.2.1 Fields of Applications. These cables are used;

- on the machinery, ovens and tools which are subject to high temperatures it is also used in the spaces having a high ambient temperature because of their silicon rubber characteristics.

- as a control and power supply cable on the machinery and installations which are operating in the spaces where in high ambient temperatures prevail.

- as a fixed control and power supply cable on the machinery installations which work in the environments wherein the ambient temperatures is quite high and the cable can be experienced with a flame or sudden temperature changes.

1.2.3.2.2 Cable Constructions

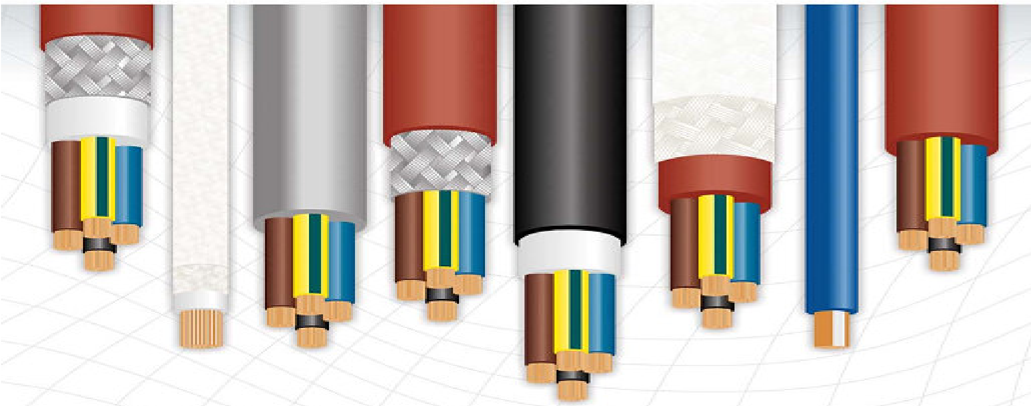


Figure 1.52 Cable construction of the Silicon Cable

1.2.3.3 Ship&Marine Cables

1.2.3.3.1 Fields of Applications. These cables are used;

- at shipboards shipyards and seaports,

- on every type of sea crafts,

- in humid, dry, wet, closed or open spaces,

- at those sites which need a high mechanical protection under the hard working conditions field of use as a power supply cable on the lighting systems of ships,

- at those sites which have to be protected against the external elektromegnetic effects,

- at those sites which need a high mechanical protection under the hard working conditions,

- at shipboards shipyards and seaports; on every type of sea crafts in humid, dry, wet, closed or open spaces; on the radio and communication sets,

- on the control and measurement systems,

- on the navigation systems, control and command circuits and alarm systems,

- fixed installation where are not used the communication tools.

1.2.3.3.2 Cable Constructions

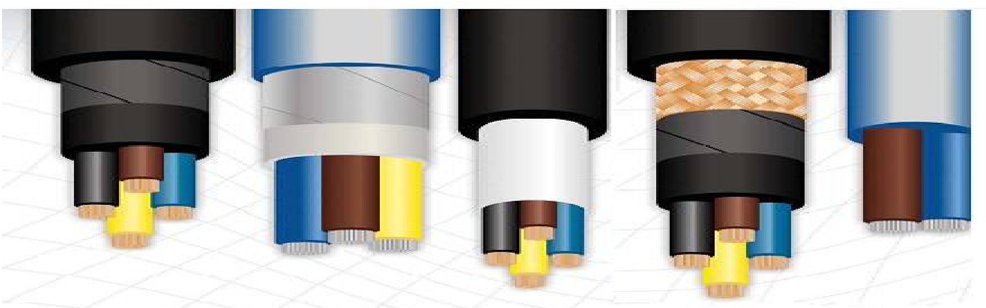


Figure 1.53 Cable construction of the Ship&Marine Cable

1.2.3.4 Lift&Cran Cables

1.2.3.4.1 Fields of Applications. These cables are used;

- for trolley systems, transfer lines, machine-tools especially on hosting devices, lift, crane and container bridges,

- on the machinery and equipment which are operating in motion,

- especially in the dr yor humid, open or closed spaces where very heavy mechanical stres exits,

- in the mine quarries, construction sites, cold and hot environments.

1.2.3.4.2 Cable Constructions

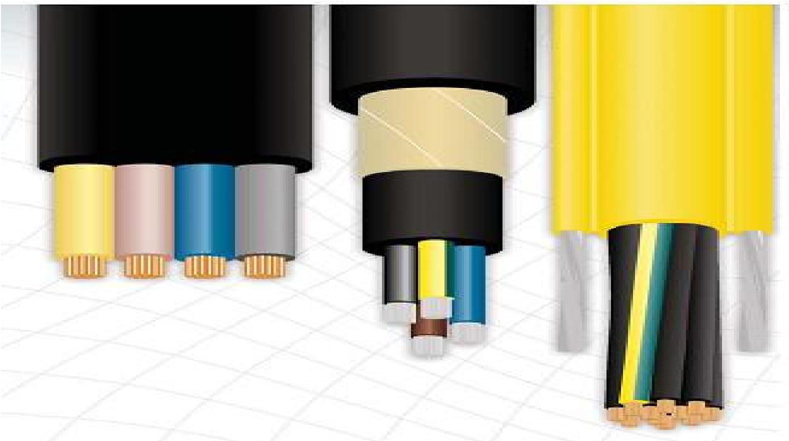


Figure 1.54 Cable construction of the Lift&Cran Cable

1.3 Production of Cable in Turkey and in the World

Here, cable manufacturing rates in the world and in Turkey are given according to the types of the cables.

1.3.1 Production of Wire and Cable in the World

In Table 1.8 world cable production rates between 1999 and 2002 are given.

Table 1.8 Production of wire and cable in world (tonnes)

PRODUCTION (000 tonnes)	1999	2000	2001	2002
Energy Cables	3690	3995	3951	4077
Copper Energy Cables	2311	2442	2444	2556
Aluminium Energy Cables	693	726	733	753
Telecomunication Cables	798	837	748	610
Telecomunication Data Cables	699	768	687	652
Wire Bobbin	2075	2174	2137	2200
Total	10265	10942	10700	10848

In Table 1.9 production of wire and cable in world are given as million USD $.

Table 1.9 Production of wire and cable in world (million USD $)

PRODUCTION (million USD $)	1999	2000	2001	2002
Energy Cables	15952	17803	16827	17079
Copper Energy Cables	15208	16566	15901	16448
Aluminium Energy Cables	3566	3645	3804	3795
Telecomunication Cables	5636	5957	5208	4071
Telecomunication Data Cables	9124	10034	8807	7713
Fiber Optic Cable	7628	11272	10238	4945
Wire Bobbin	6361	7036	6633	6661
Total	63475	72311	67418	60712

1.3.2 Consumption of Wire and Cable in World

To 2002, total consumption of wire and cable is nearly 10851000 tonnes. According to countries, Chine had the most consumption. It is 2051000 tonnes. And USA were second in consumption.

Customs schedule statistical position number of wire and cable are given in Table 1.10.

Table 1.10 Customs schedule statistical position number of wire and cable

Position Number	Caple Type and Properties
761490000000	ropes and woven ropes etc. which made of aluminium (which are othershapes)
761410000000	ropes and woven ropes etc. which made of aluminium (which are steel eyes)
741300990000	Copper alloy; thin, thick rope, woven
740400910000	Copper, slag and scrap; copper-zinc alloys
740400990000	Copper slag and scrap; other
740400100000	Copper slag and scrap; from refined copper
900110101000	Fiber glass image transferring cables
731210510000	Iron/steel bunching wires, copper or zinc covered d: =<3 mm
731210590000	Iron/steel bunching wires, other d: =<3 mm
731210100000	Iron/steel bunching wires, rope, cables for civilian air
731210790000	Iron/steel bunching wires, etc. cross section >3 mm
731210710019	Iron/steel not bunching wires, not covering cross section >3 mm
731210750000	Iron/steel bunching wires, covering zinc, cross section >3 mm
731210710011	Front stretched bunching wires of iron/steel, not covering cross section >3 mm
854449809019	Other electricity conductors d:=<80 V.
854420009019	Other coaxial cables and conductors
854420001019	Other soil and under water cables
854449801019	Other soil and under water cables d:=<80 V.
854449809011	Other cables for transferring of electricity energy d:=<80 V.
854449801011	Other soil and under water cables for transferring of electricity energy d:=<80 V.
854470000000	Fiber optic cables
731210990000	Rope and cables (including closed ropes) not covering, covering zinc, etc.
731210840000	Rope and cables (including closed ropes) not covering, covering zinc, 12 cross section=< 24 mm
731210860000	Rope and cables (including closed ropes) not covering, covering zinc, 24 cross section=< 48 mm

731210820000	Rope and cables (including closed ropes) not covering, covering zinc, 3 cross section=< 12 mm
731210880000	Rope and cables (including closed ropes) not covering, covering zinc, cross section>48 mm
900110901000	Cables which aren't processed in optic style
900110909100	Cables which are processed in optic style
900110909900	Optic fiber bunchs and cables which are processed in optic style
731210300000	Wires, rope and cables which arebunchedstainless steel
741300910000	Slim and thick rope, cable and woven rope which are made of refined copper
854449201019	Other soil and under water cables which belong to telecomunication d:=<80 V.
854449209019	Other cables which are used in telecomunication d:=<80 V.
854449209011	Other soil and under water cables for telegraph and telephone line d:=<80 V.
854420009011	Coaxial cable and conductors for telegraph and telephone line
854420001011	Soil and under water cables for telegraph and telephone line
854449201011	Soil and under water cables for telegraph and telephone line d:=<80 V.

1.3.3 Cable&Wire Import&Export in World

1.3.3.1 Cable&Wire Export&Import in World in 2004

Table 1.11 Cable&Wire Export in World in 2004.

Position Number	Caple Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
761490000000	ropes and woven ropes etc. which made of aluminium (which are othershapes)	4055148	9329077	2.30
761410000000	ropes and woven ropes etc. which made of aluminium (which are steel eyes)	9602478	18606715	1.94
741300990000	Copper alloy; thin, thick rope, woven	95749	236656	2.47
740400910000	Copper, slag and scrap; copper-zinc alloys	978351	1577273	1.61
740400990000	Copper slag and scrap; other	2128156	2214653	1.04
740400100000	Copper slag and scrap; from refined copper	1422040	2375230	1.67
900110101000	Fiber glass image transferring cables	15855	310929	1.96
731210510000	Iron/steel bunching wires, copper or zinc covered d: =<3 mm	36938788	65051729	1.76
731210590000	Iron/steel bunching wires, other d: =<3 mm	55858	60456	1.08
731210100000	Iron/steel bunching wires , rope, cables for civilian air	95	449	4.73
731210790000	Iron/steel bunching wires , etc. d >3 mm	85664	87238	1.02
731210710019	Iron/steel not bunching wires, not covering cross section >3 mm	812995	891117	1.10
731210750000	Iron/steel bunching wires, covering zinc, cross section >3 mm	597163	610446	1.02
731210710011	Front stretched bunching wires of iron/steel, not covering cross section >3 mm	197891	234347	1.18
854449809019	Other electricity conductors d:=<80 V.	3194190	11257639	3.52
854420009019	Other coaxial cables and conductors	4738366	13406423	2.83
854420001019	Other soil and under water cables	4865795	10286036	2.11
854449801019	Other soil and under water cables d:=<80 V.	183756	441323	2.40
854449809011	Other cables for transferring of electricity energy d:=<80 V.	4022280	12123574	3.01
854449801011	Other soil and under water cables for transferring of electricity energy d:=<80 V.	1144189	3744167	3.27
854470000000	Fiber optic cables	4563577	20029595	4.39
731210990000	Rope and cables (including closed ropes) not covering, covering zinc, etc.	560228	560236	1.00
731210840000	Rope and cables (including closed ropes) not covering, covering zinc, 12 cross section=< 24 mm	4018658	4423416	1.10
731210860000	Rope and cables (including closed ropes) not covering, covering zinc, 24 cross section=< 48 mm	1737756	1927311	1.11
731210820000	Rope and cables (including closed ropes) not covering, covering zinc, 3 cross section=< 12 mm	1125544	1380814	1.23
731210880000	Rope and cables (including closed ropes) not covering, covering zinc, cross section>48 mm	22965	22376	0.97
900110901000	Cables which aren't processed in optic style	1304	7047	5.40
900110909100	Cables which are processed in optic style	272	17249	6.34

900110909900	Optic fiber bunchs and cables which are processed in optic style	5699	47971	8.42
731210300000	Wires, rope and cables which arebunchedstainless steel	228447	450082	1.97
741300910000	Slim and thick rope, cable and woven rope which are made of refined copper	37226723	131411601	3.53
854449201019	Other soil and under water cables which belong to telecomunication d:=<80 V.	2289755	5898676	2.58
854449209019	Other cables which are used in telecomunication d:=<80 V.	12843194	32101978	2.50
854449209011	Other soil and under water cables for telegraph and telephone line d:=<80 V.	123274	450203	3.65
854420009011	Coaxial cable and conductors for telegraph and telephone line	117356	274835	2.34
854420001011	Soil and under water cables for telegraph and telephone line	171795	474893	2.76
854449201011	Soil and under water cables for telegraph and telephone line d:=<80 V.	10948712	32337332	2.95
Total		**151120066**	**384661092**	**2.55**

Table 1.12 Cable&Wire Import in World in 2004

Position Number	**Caple Type and Properties**	**Weight, kg**	**Price, $**	**Unit Price, $/Kg**
761490000000	ropes and woven ropes etc. which made of aluminium (which are othershapes)	100134	335732	3.35
761410000000	ropes and woven ropes etc. which made of aluminium (which are steel eyes)	2875	11045	3.84
741300990000	Copper alloy; thin, thick rope, woven	90443	545909	6.04
740400910000	Copper, slag and scrap; copper-zinc alloys	4396715	7423353	1.69
740400990000	Copper slag and scrap; other	1178262	2558173	2.17
740400100000	Copper slag and scrap; from refined copper	29399638	70354076	2.39
900110101000	Fiber glass image transferring cables	18841	2537466	1.35
731210510000	Iron/steel bunching wires, copper or zinc covered d: =<3 mm	2082361	4876221	2.34
731210590000	Iron/steel bunching wires, other d: =<3 mm	1123741	1364591	1.21
731210100000	Iron/steel bunching wires, rope, cables for civilian air	1002	2826	2.82
731210790000	Iron/steel bunching wires, etc. cross section >3 mm	193855	474891	2.45
731210710019	Iron/steel not bunching wires, not covering cross section >3 mm	4720	32189	6.82
731210750000	Iron/steel bunching wires, covering zinc, cross section >3 mm	187438	988066	5.27
731210710011	Front stretched bunching wires of iron/steel, not covering cross section >3 mm	2412274	2404372	1.00
854449809019	Other electricity conductors d:=<80 V.	2546835	19250644	7.56
854420009019	Other coaxial cables and conductors	997708	6698581	6.71
854420001019	Other soil and under water cables	104860	818451	7.81

854449801019	Other soil and under water cables d:=<80 V.	2858	75165	2.63
854449809011	Other cables for transferring of electricity energy d:=<80 V.	372991	3420069	9.17
854449801011	Other soil and under water cables for transferring of electricity energy d:=<80 V.	8939	59745	6.68
854470000000	Fiber optic cables	621528	5447197	8.76
731210990000	Rope and cables (including closed ropes) not covering, covering zinc, etc.	110273	561321	5.09
731210840000	Rope and cables (including closed ropes) not covering, covering zinc, 12 cross section=< 24 mm	1161002	1152845	0.99
731210860000	Rope and cables (including closed ropes) not covering, covering zinc, 24 cross section=< 48 mm	108406	295228	2.72
731210820000	Rope and cables (including closed ropes) not covering, covering zinc, 3 cross section=< 12 mm	810730	1003980	1.24
731210880000	Rope and cables (including closed ropes) not covering, covering zinc, cross section>48 mm	88598	213481	2.41
900110901000	Cables which aren't processed in optic style	238	43176	1.81
900110909100	Cables which are processed in optic style	1206	158021	1.31
900110909900	Optic fiber bunchs and cables which are processed in optic style	39480	5177196	1.31
731210300000	Wires, rope and cables which arebunchedstainless steel	344657	2475448	7.18
741300910000	Slim and thick rope, cable and woven rope which are made of refined copper	135685	737708	5.44
854449201019	Other soil and under water cables which belong to telecomunication d:=<80 V.	215474	676608	3.14
854449209019	Other cables which are used in telecomunication d:=<80 V.	795861	3142391	3.95
854449209011	Other soil and under water cables for telegraph and telephone line d:=<80 V.	45	430	9.56
854420009011	Coaxial cable and conductors for telegraph and telephone line	125049	1093911	8.75
854420001011	Soil and under water cables for telegraph and telephone line	31527	252856	8.02
854449201011	Soil and under water cables for telegraph and telephone line d:=<80 V.	13139	41090	3.13
Total		**49831277**	**146812980**	**2.95**

Table 1.13 Cable&Wire Export in World in 2005

Position Number	Caple Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
761490000000	ropes and woven ropes etc. which made of aluminium (which are othershapes)	2084877	5034962	2.41
761410000000	ropes and woven ropes etc. which made of aluminium (which are steel eyes)	9207164	18747179	2.04
741300990000	Copper alloy; thin, thick rope, woven	105339	410495	3.90
740400910000	Copper, slag and scrap; copper-zinc alloys	531530	1240239	2.33

740400990000	Copper slag and scrap; other	7272232	11738141	1.61
740400100000	Copper slag and scrap; from refined copper	7279502	19165884	2.63
731210510000	Iron/steel bunching wires, copper or zinc covered d: =<3mm	34987850	73049873	2.09
731210590000	Iron/steel bunching wires, other d: =<3 mm	197030	184022	0.93
731210100000	Iron/steel bunching wires, rope, cables for civilian air	1988	5137	2.58
731210790000	Iron/steel bunching wires, etc. cross section >3 mm	51603	74336	1.44
731210710019	Iron/steel not bunching wires, not covering cross section >3 mm	536056	612451	1.14
731210750000	Iron/steel bunching wires, covering zinc, cross section >3 mm	314927	339680	1.08
731210710011	Front stretched bunching wires of iron/steel, not covering cross section >3 mm	497257	571655	1.15
854449809019	Other electricity conductors d:=<80 V.	3131209	12399292	3.96
854420009019	Other coaxial cables and conductors	5065035	18734756	3.70
854420001019	Other soil and under water cables	3848530	10696832	2.78
854449801019	Other soil and under water cables d:=<80 V.	752393	1968038	2.62
854449809011	Other cables for transferring of electricity energy d:=<80 V.	3910298	17675849	4.52
854449801011	Other soil and under water cables for transferring of electricity energy d:=<80 V.	982253	3652929	3.72
854470000000	Fiber optic cables	3945710	23019679	5.83
731210990000	Rope and cables (including closed ropes) not covering, covering zinc, etc.	186447	432740	2.32
731210840000	Rope and cables (including closed ropes) not covering, covering zinc, 12 cross section=< 24 mm	4831107	6237861	1.29
731210860000	Rope and cables (including closed ropes) not covering, covering zinc, 24 cross section=< 48 mm	3232390	3999796	1.24
731210820000	Rope and cables (including closed ropes) not covering, covering zinc, 3 cross section=< 12 mm	2101550	2372736	1.13
731210880000	Rope and cables (including closed ropes) not covering, covering zinc, cross section>48 mm	246598	307710	1.25
900110909900	Optic fiber bunchs and cables which are processed in optic style	26456	111208	4.20
731210300000	Wires, rope and cables which arebunchedstainless steel	244692	459697	1.88
741300910000	Slim and thick rope, cable and woven rope which are made of refined copper	39393111	173414399	4.40
854449201019	Other soil and under water cables which belong to telecomunication d:=<80 V.	623817	2030970	3.26
854449209019	Other cables which are used in telecomunication d:=<80 V.	13987455	40991302	2.93
854449209011	Other soil and under water cables for telegraph and telephone line d:=<80 V.	41086	166509	4.05
854420009011	Coaxial cable and conductors for telegraph and telephone line	91009	332314	3.65
854420001011	Soil and under water cables for telegraph and telephone line	86496	302333	3.50
854449201011	Soil and under water cables for telegraph and telephone line d:=<80 V.	12530379	42236602	3.37
Total		**162325627**	**492718748**	**3.04**

Table 1.14 Cable&Wire Import in World in 2005

Position Number	Caple Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
761490000000	ropes and woven ropes etc. which made of aluminium (which are othershapes)	73421	232414	3.17
761410000000	ropes and woven ropes etc. which made of aluminium (which are steel eyes)	8746	154711	1.77
741300990000	Copper alloy; thin, thick rope, woven	88678	577299	6.51
740400910000	Copper, slag and scrap; copper-zinc alloys	1843434	3641071	1.98
740400990000	Copper slag and scrap; other	268360	823492	3.07
740400100000	Copper slag and scrap; from refined copper	7992684	24764762	3.10
900110101000	Fiber glass image transferring cables	24262	3261535	1.34
731210510000	Iron/steel bunching wires, copper or zinc covered d: =<3 mm	2313757	5607871	2.42
731210590000	Iron/steel bunching wires, other d: =<3 mm	2997101	3612015	1.21
731210100000	Iron/steel bunching wires, rope, cables for civilian air	69	27635	4.01
731210790000	Iron/steel bunching wires, etc. cross section >3 mm	110890	380377	3.43
731210710019	Iron/steel not bunching wires, not covering cross section >3 mm	14121	60145	4.26
731210750000	Iron/steel bunching wires, covering zinc, cross section >3 mm	138370	1077487	7.79
731210710011	Front stretched bunching wires of iron/steel, not covering cross section >3 mm	6164511	6269019	1.02
854449809019	Other electricity conductors d:=<80 V.	5560919	34106276	6.13
854420009019	Other coaxial cables and conductors	1908632	9100273	4.77
854420001019	Other soil and under water cables	242438	1474291	6.08
854449801019	Other soil and under water cables d:=<80 V.	25493	78137	3.07
854449809011	Other cables for transferring of electricity energy d:=<80 V.	635312	4807561	7.57
854449801011	Other soil and under water cables for transferring of electricity energy d:=<80 V.	18014	150805	8.37
854470000000	Fiber optic cables	375897	4212075	1.12
731210990000	Rope and cables (including closed ropes) not covering, covering zinc, etc.	231970	923827	3.98
731210840000	Rope and cables (including closed ropes) not covering, covering zinc, 12 cross section=< 24 mm	1714499	2232118	1.30
731210860000	Rope and cables (including closed ropes) not covering, covering zinc, 24 cross section=< 48 mm	322640	876486	2.72
731210820000	Rope and cables (including closed ropes) not covering, covering zinc, 3 cross section=< 12 mm	968498	1509648	1.56
731210880000	Rope and cables (including closed ropes) not covering, covering zinc, cross section>48 mm	36959	219508	5.94
900110901000	Cables which aren't processed in optic style	20831	2662966	1.28
900110909100	Cables which are processed in optic style	1401	104355	7.45

900110909900	Optic fiber bunchs and cables which are processed in optic style	47788	5322200	1.11
731210300000	Wires, rope and cables which arebunchedstainless steel	451642	2912349	6.45
741300910000	Slim and thick rope, cable and woven rope which are made of refined copper	211003	1241888	5.89
854449201019	Other soil and under water cables which belong to telecomunication d:=<80 V.	134091	502874	3.75
854449209019	Other cables which are used in telecomunication d:=<80 V.	695274	3193840	4.59
854449209011	Other soil and under water cables for telegraph and telephone line d:=<80 V.	6034	33414	5.54
854420009011	Coaxial cable and conductors for telegraph and telephone line	82929	578392	6.97
854420001011	Soil and under water cables for telegraph and telephone line	103130	845915	8.20
854449201011	Soil and under water cables for telegraph and telephone line d:=<80 V.	23415	72818	3.11
Total		**35857656**	**127744961**	**3.56**

Table 1.15 Cable&Wire Export in World in 2006

Position Number	Caple Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
731210810000	Cables and rope which made of iron or steel; zinc covered, 3<d=<12 mm	962446	1325829	1.38
731210980000	Rope and cables, not covered or zinc covered	777383	1068425	1.37
740400100000	Copper slag and scrap; from refined copper	3307471	15095244	4.56
741300200000	Slim and thick rope, cable and woven rope from refined copper	32426425	226336935	6.98
741300800000	Slim and thick rope, cable and woven rope from copper alloy	178163	1363169	7.65
761410000000	ropes and woven ropes etc. which made of aluminium (which are steel eyes)	6780623	19966019	2.94
761490000000	ropes and woven ropes etc.which made of aluminium (which are other shapes)	923148	3219363	3.49
854420009011	Coaxial cable and conductors for telegraph and telephone line	291042	1601763	5.50
854420009019	Other coaxial cables and conductors	6535058	35702846	5.46
854470000000	Fiber optic cables	4012985	28542301	7.11
Total		**56194744**	**334221894**	**5.95**

Table 1.16 Cable&Wire Import in World in 2006

Position Number	Caple Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
731210810000	Cables and rope which made of iron or steel; zinc covered, 3<d=<12 mm	1573401	2460304	1.56
731210830000	Cables and rope which made of iron or steel; zinc covered, 12<d=<24 mm	1076949	1533921	1.42
731210850000	Cables and rope which made of iron or steel; zinc covered, 24<d=<48 mm	658061	1861447	2.83
731210980000	Rope and cables, not covered or zinc covered	277683	1104920	3.98
740400100000	Copper slag and scrap; from refined copper	3800586	22481072	5.92
741300200000	Slim and thick rope, cable and woven rope from refined copper	317730	2212805	6.96
741300800000	Slim and thick rope, cable and woven rope from copper alloy	35274	439083	12.45
854420001019	Other soil and underwater cables	128464	718827	5.60
854420009011	Coaxial cable and conductors for telegraph and telephone line	29810	169863	5.70
854420009019	Other coaxial cables and conductors	1577499	8995155	5.70
854470000000	Fiber optic cables	187120	4661210	24.91
900110909100	Cables which are processed in optic style	831	162419	195.45
Total		**9663408**	**46801026**	**4.84**

Table 1.17 Cable&Wire Export in World in 2007

Position Number	Cable Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
731210810000	Cables and rope which made of iron or steel; zinc covered, 3<d=<12 mm	826213	1574913	1.91
731210980000	Rope and cables not covered/covered zinc	1372333	2112171	1.54
740400100000	Copper slag and scrap; from refined copper	475105	1788913	3.77
741300200000	Slim and thick rope, cable and woven rope from refined copper	30119343	235996415	7.84
741300800000	Slim and thick rope, cable and woven rope from copper alloy	291710	2664851	9.14
761410000000	ropes and woven ropes etc.which made of aluminum (which are steel eyes)	8290980	25085958	3.03
761490000000	ropes and woven ropes etc.which made of aluminum (which are other shapes)	2037842	7274196	3.57

853670001000	connective for optic fibers, optic fibers bunches/cables; from plastic	59425	682044	11.48
853670003000	connective for optic fibers, optic fibers bunches/cables; from copper	11500	118927	10.34
853670005000	connective for optic fibers, optic fibers bunches/cables; from iron or steel	49657397	146192228	2.94
854420009011	Coaxial cable and conductors for telegraph and telephone line	153390	1284694	8.38
854420009019	Other coaxial cables and conductors	7154588	46549091	6.51
854449201919	Other cables used in telecommunication (V=<80V)	6836656	40420435	5.91
854449911111	Soil and underwater cables for transferring electric energy (d<0,51mm, V=<80 V)	34466407	156683246	4.55
854449911119	Other soil and underwater cables (d< 0,51mm,V=<80 V)	3655129	17916900	4.90
854449911911	Other cables for transferring electric energy (d<0,51mm, V=<80 V)	4852402	27272600	5.62
854449931119	Other soil and underwater cables (V>80 V)	90244	632757	7.01
854449931911	Other cables for transferring electric energy (V>80 V)	1042012	7572893	7.27
854449951119	Other soil and underwater cable (V<80V and V>1000V)	4873228	22774372	4.67
854449951900	Other cables (V<80V and V>1000V)	53992012	249462257	4.62
854449991100	Soil and underwater cable with silicon and acetate (V<1000V)	507819	2519833	4.96
854470000000	Fiber optic cables	4777236	39671845	8.30
Total		**215542971**	**1036251539**	**4.81**

Table 1.18 Cable&Wire Import in World in 2007

Position Number	Cable Type and Properties	Weight, kg	Price, $	Unit Price, $/Kg
731210810000	Cables and rope which made of iron or steel; zinc covered, 3<d=<12 mm	1809903	3853471	2.13
731210830000	Cables and rope which made of iron or steel; zinc covered, 12<d=<24 mm	2983971	4045384	1.36
731210850000	Cables and rope which made of iron or steel; zinc covered, 24<d=<48 mm	668939	1521660	2.27
731210890000	Cables and rope which made of iron or steel; zinc covered, d>48 mm	153288	419320	2.74
731210980000	Rope and cables not covered/covered zinc	859871	2397036	2.79
740400100000	Copper slag and scrap; from refined copper	1616043	9993991	6.18

741300200000	Slim and thick rope, cable and woven rope from refined copper	293419	2372269	8.08
741300800000	Slim and thick rope, cable and woven rope from copper alloy	55755	722276	12.95
853670001000	connective for optic fibers, optic fibers bunches/cables; from plastic	85656	1237602	14.45
853670002000	connective for optic fibers, optic fibers bunches/cables; from ceramic	447185	2661354	5.95
853670003000	connective for optic fibers, optic fibers bunches/cables; from copper	1506	34224	22.73
853670005000	connective for optic fibers, optic fibers bunches/cables; from iron or steel	21027637	105546868	5.02
854420001019	Other soil and underwater cables	113204	1361263	12.02
854420009011	Coaxial cable and conductors for telegraph and telephone line	26847	143633	5.35
854420009019	Other coaxial cables and conductors	2099862	15547414	7.40
854449201919	Other cables used in telecommunication (V=<80V)	1203571	14457454	12.01
854449911111	Soil and underwater cables for transferring electric energy (d<0,51mm, V=<80 V)	41739	388207	9.30
854449931119	Other soil and underwater cable (V>80V)	57533	435907	7.58
854449951119	Other soil and underwater cable (V<80V and V>1000V)	195224	2567120	13.15
854449951900	Other cables (V<80V and V>1000V)	3102803	30460943	9.82
854470000000	Fiber optic cables	851123	8864953	10.42
900110909100	Cables which are processed in optic style	114	139248	1221.47
Total		**37695193**	**209171597**	**5.55**

1.4 Previous Studies About Cable Recovery and Reuse

1.4.1 Recycling of Cable Waste in Netherlands

Every year approximately 55.000 tons of cable scrap is produced in the Netherlands. The scrap contains 10.000-15.000 tons of lead cables. The remaining scrap cables are plastic insulated cables. The scrap includes all type of cables and wires. The scrap is produced due to the (economic) end of life of cables, production waste, surplus during installation and repairment.

Cable scrap is mainly recycled to recover valuable metals. The general metal content of cable scrap is given in Table 1.19.

Table 1.19 Composition of cable scrap.

Material	Lead cable	Plastic insulated cable
metals (Pb, Cu, AI, Fe)	70-80%	40-60%
Other (bitumen, paper, plastics)	20-30%	40-60%

Lead cable scrap contains 70-80% of metals and plastic insulated cable scrap contains less metal (40-60%).

In the past cables were recycled by simply burning them. By burning the impregnated paper of lead cables the temperature is increased above 327 °C, melting point of lead. Lead melts and the ingots are produced. The copper remains solid and can be collected after burning. Cables with aluminum conductors could not be recycled by burning due to the poor temperature control du-ring this process, which resulted in melting both aluminum and lead.

Although burning cables was a simple and efficient technology to separate copper from lead, the technique was being prohibited by the government in the Netherlands because of the emissions of heavy metals, dust and dioxines into the environment. The Dutch government band burning by not continuing the appropriate license for cable burning.

To assure that the optimal technologies are used to recover metals from cable waste the efficiency of various separation processes was determined. The efficiency of a separation process is being described by the achieved recovery and the grade (purity) of the metal. General relation between recovery and grade achieved by a separation process is shown in figure 1.55. The influence of the used technology is also shown. With a beter technology higher recoveries and grades can be achieved.

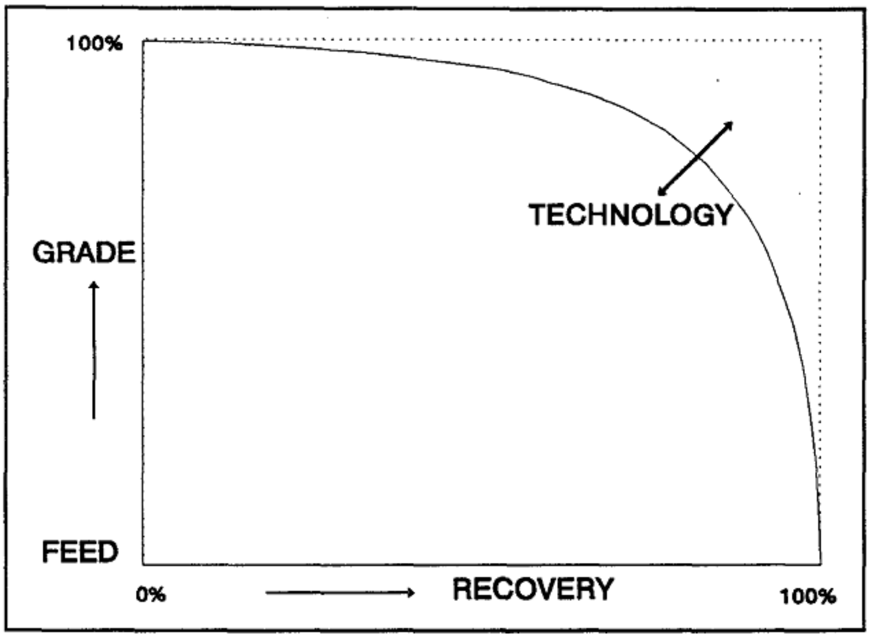


Figure 1.55 Recovery and grade

In general two technologies are being used to recycle cable scrap:

- stripping of cables
- (Cryogenic) shredding of cables.

Two examples of these technologies are presented in this paper to give an impression of these processes. In practice, the obtained grades and recoveries vary and depend on the type of cable and processor.

1.4.1.1 Stripping of Cables

The stripping technology is shown in figure 1.56.

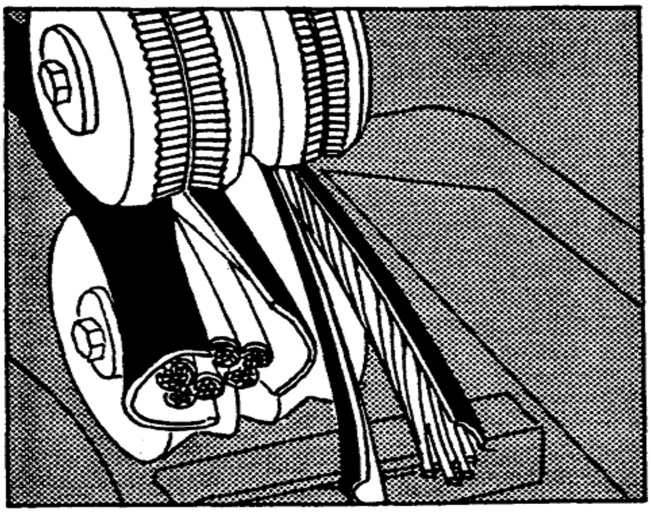


Figure 1.56 Stripping of cables

The insulation material is being split and peeled of the conductor. The stripping machine is manually fed and therefore has a low capacity. Cables with a small diameter cannot be stripped and must be shredded.

In table 1.20 an example is shown of the results of stripping a lead energy cable with a copper conductor.

Table 1.20 Results of stripping lead energy cables (Cu)

Fraction	Material	Recovery	Grade
Copper	Cu Bitumen	97 %	99 % 1%
Lead	Pb Paper, bitumen	100 %	90 % 2%
Iron	Fe Paper, bitumen	100 %	94 % 6 %
Residual	Paper, bitumen Cu	3%	96 % 4%

Four fractions are being produced during stripping of the energy cable. The results show that a copper product is produced with a grade of 99%, recovering 97% of the copper. All the lead is recovered with a grade of 98%. The residual waste contains 4% copper and 3% copper is lost.

(Cryogenic) shredding of cables In the shredding process the cables are comminuted to liberate the metal from the insulator.Before the cables are shredded they can be treated with liquid nitrogen to make the insulation material more brittle. After liberation the metal particles are separated from the insulation particles by differences in density, magnetic and conductive properties.

The shredding process has a high capacity and all types of cables can be recycled.

An example of a shredding process is schematically shown in figure 1.57.

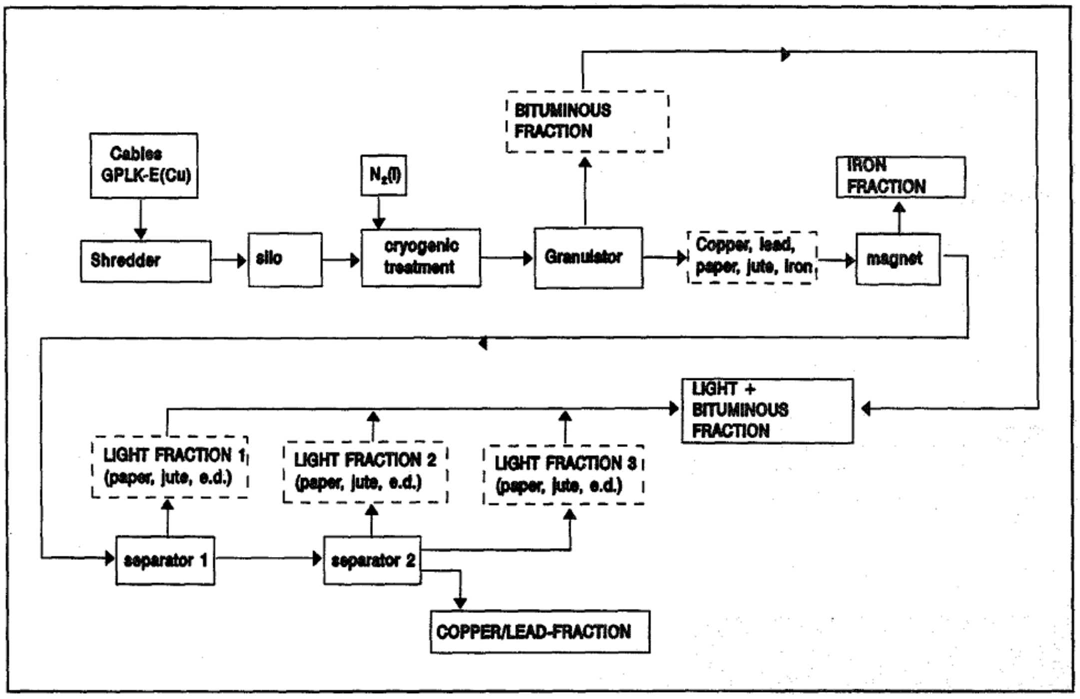


Figure 1.57 Shredding process

The results of shredding lead energy cables with a copper conductor are given in Table 1.21 All the residual waste streams are collected.

Table 1.21 Results of shredding energy cables (Cu)

Fraction	Material	Recovery	Grade
Copper/Lead	Cu Pb	83 % 100 %	26 % 73 %
Iron	Fe Cu Paper, bitum.	100 % 2%	97 % 2% 1%
Residual	Paper, bitum. Cu	15 %	90 % 9%

As can be seen, a mixture of 26% copper and 73% lead is produced. The residual waste still contains 9% copper and 15% copper is lost.

1.5 CABLE RECOVERY TODAY

There are two major ways to recover wasted cables. After its use, PVC wire and cable can be recycled, or in some cases, incinerated. Below, these two processes are explained in details in terms of waste cable.

1.5.1 Incineration

In terms of waste incineration, it is clear that chlorinated substances in the feedstock are an essential component for the formation of dioxins, however there is conflicting evidence about whether the chlorine content of waste feedstock has a significant impact on dioxin emissions. Evidence indicates that for commercial scale incinerators, combustion conditions (flue gas temperature and residence time, combustion efficiency, etc.) are the dominant factor in determining stack emissions. For uncontrolled combustion (e.g., backyard burning and accidental fires) the chlorine content of waste feedstock may have more impact on dioxin emissions. Incineration of waste wire and cable is no longer allowed in Europe, since it leads to the release of heavy metals and dioxins in the air.

1.5.2 Recycling

Scrap created during manufacturing or installation as well as end-of-life wire and cable can be collected and recycled. For this purpose all of the various materials – metal, plastic and others – must be separated. The wires are typically chopped, and the vinyl is then separated from the metal through electrostatic separation, which uses electrical charges to extract the metal from the plastic. Once separated, the vinyl is shredded and recycled into second generation products, such as sound-deadening panel for car doors. The presence of various additives, which may generate toxic gases and release heavy metals, presents a potential barrier to recycling. (Environmental Building News 1994)

In Turkey most of cables (exception of fiber optic cables and etc. because of there isn't any valuable material in it) are recycled.

1. Manufacturer (for Cables) → 2. User of Cables → 3. Waste Cable

→ 4. Collector → 5. Separator → 6. Buyers of These Wastes

→ 7. Recycling → 8. Reusing Areas of These Wastes

Figure 1.58 Cable Recovering Flow Process

In 1997, world-wide over 1,800,000 tones of insulated wire and cable scrap was generated. This scrap contains on average about 60% metal or 1,080,000 tones and 40% plastics or 720,000 tones. The conducting metal in this scrap is primarily copper. Though, power transmission cables have aluminum as the conducting metal. Utilities use insulated aluminum power cable as outside distribution cable and primarily insulated copper wire for inside distribution. Building, communication, electronics and automotive markets normally use copper as the conducting metal.

This cable scrap is valuable, mainly because it contains copper and aluminum metal, although the plastic also has value and can be recycled or reused. An industry has specifically developed to recover these metals.

Cable scrap arises in all countries, OECD and non-OECD. Most scrap cable is recycled domestically in OECD countries; only an estimated 15% of cable scrap is exported, not so much because of lack of domestic capability but because of market forces. The USA, W. Europe, Japan, Canada, Singapore and Australia ship cable scrap to the developing countries; in particular, China, Vietnam, S. Korea, Mexico, Indonesia, Malaysia, Thailand, Taiwan, India, Pakistan, Argentina, Brazil and Chile. Export of metal-containing cable scrap to developing countries amounts to an estimated 80,000 tones from the USA, some 72,000 tones from Japan and an estimated 20,000 tones from Europe annually. About 30% of these scrap cables are re-used rather than recycled in non-OECD countries. Cable scrap is shipped according to widely accepted trade specifications and classifications.

The dominant plastic materials used in insulated cables are PVC and polyethylene. In the USA, these plastics are used almost equally. In Western Europe and Japan the use of PVC is greater than the use of polyethylene. Both plastics are thermo-plastics and can therefore be re-melted during the recycling process.

Cable scrap is generated by cable manufacturers and end-users such as utility and telephone companies, manufacturers of electronic and electrical equipment, and electrical contractors. This is pre-consumer scrap (or 'new scrap').

On the other hand, cable scrap recovered while replacing old cable lines with new ones or from end-of life electronic equipment is called post-consumer scrap (or 'old scrap').

Utilities, which are a major source of scrap, generate pre-consumer scrap in the installations of new lines -- reel ends, etc. -- and post-consumer scrap from dismantling old lines. This scrap arises in all countries whether OECD and non-OECD, therefore each country will require some form of domestic treatment for this coated cable scrap. As raw materials have become more expensive and companies more environmentally conscious over the past decade, many continuous improvement programs have started bringing a reduction in production wastes.

Pre-consumer cable scrap is preferred by the cable scrap processor; because it is a "known" waste material (some countries do not consider these materials as "wastes"). For example, a power cable manufacturer generates a waste stream that usually contains only aluminum metal and polyethylene, while a manufacturer of communication cable often generates a waste stream that contains only copper metal and PVC. Post-consumer scrap is the same material as pre-consumer but the wastes are more dispersed and need dismantlement. These wastes require transport and co-ordination to be environmentally and cost effectively recycled.

The predominant way of recovering the metal from cable scrap in the developed countries is automated cable chopping. The technology is available all over the world. Most cable chopping plants process only copper cable scrap, a few only process aluminum cable scrap, and some operate both a line for aluminum and another for copper cable scrap.

Systems vary in size from 225-680 kg/hr. to 4,770-5,455 kg/hr. and cost, based on 1997 prices; vary from $150,000 for small machinery to $1,800,000 for larger machines. Cable processors in Europe tend to install small to medium-sized lines handling 0.5 tones to 3 tones/hr and which tend to produce an overall finer chop grind than U.S. cable processors. U.S. cable choppers typically use larger lines with capacities reaching at least 5 tones/hr. Many of these systems are suitable for developing countries.

In North America, about 100 plants operate wire chopping lines with a production of 540,000 – 640,000 tones/yr. Cable chopping lines in Japan process some 500,000 tones of cable scrap in approximately 100 plants, including 10 major ones. Cable chopping lines are also in Western Europe, Morocco, Tunisia, Australia, Brazil, Argentina, and Chile. China has 6-7 cable chopping plants, and Russia recently acquired one or two plants from a US manufacturer.

1.5.2.1 Cable Recycling in Turkey

The process consists of pre-sorting, cable stripping, cable chopping, granulation, screening, and density separation.

1.5.2.1.1 Pre-sorting. Pre-sorting includes the separation of long cable sections, by type of insulation, by conductor diameter, or as plated or unplated conductor, or densely baled cable, whereas pieces of ferrous and non-ferrous metal from loose cable can be fed directly to the shredder. The pre-sorting is the most important element of the environmentally sound management of cables scrap, it also allows to get maximum value for the recovered metal scrap and to make further separation of plastics easier. Long cable sections are sheared into lengths of about 1m so that they can be fed into the granulator, while densely baled cable has to be broken up into loose streams. Most importantly, pre-sorting includes sorting copper- from aluminum-containing cable. These machines process anything from 8 cm diameter cable to thin cable of about 26-gauge. Material not well-suited to such automated systems can be separated out beforehand, for example superfine "hair wire" and grease or tar-filled cables that can obstruct the system (these can be manually separated).

1.5.2.1.2 Cable Chopping. Chopping is normal in larger plants but optional in smaller plants and is usually desirable for processing long cable sections. It is the first step in reducing the size of the cable chop. Compared to shredding, cable chopping produces little if any filter dust. After cable chopping cables are shown in figure 1.59.

Figure 1.59 Cable Chopping

1.5.2.1.3 Granulation. In the primary granulator stripping of the insulator and jacketing is only partially accomplished, as the cable chops are typically about 7-8 cm in length. The secondary granulator produces maximum lengths of about 0.6 cm. Such fine chopping usually liberates most of the insulation from the cable but inevitably small amounts of metal remain embedded in the plastics. Granulation is shown in figure 1.60 and insulation granules is shown in figure 1.61.

Figure 1.60 Granulation

Figure 1.61 Insulation granules

1.5.2.1.4 Screening. To enhance the recovery of metal, some chopping lines also use screening to yield the desired chop size. The smaller the chop size the more efficient the removal of the metal. Some systems use vibrating screens that prepare the chops for final metal separation. Here the "fines" containing metal, plastic, fibres, and dirt drop through the bottom screen. The metal is recovered, while an aspirator sucks up the non-metallics. Dust collection using a cyclone collector occurs at many points throughout the system and filter system further cleans the air before exhausting. Dust particulate is shown in figure 1.62.

Figure 1.62Dust particulate

1.5.2.1.5 Density separation. Similar-size fractions of the chops that collect on the screens are then discharged and fed to an air table that is slanted in two directions. The chips enter from the rear of the table, and the mix is fluidized by air—lighter particles are lifted higher than heavier ones. Consequently, the heavier metal particles move up the table, while the lighter particles of plastic residue or "tailings" float downslope. The fluidized bed separator produces two fractions: clean metal product and essentially metal-free tailings. Generally, "middling" fractions are reprocessed again in the system or can be re-tabled.

Though all cable processors seek the best metal recovery, some metal — both loose and embedded — eludes capture. Metal content of residue streams can vary from less than 1% to more than 15%. Some cable processors have installed dry electrostatic systems. For example, electrostatic separators can reduce the metal content of tailings from 5-15% to less than 0,1%. The use of electrostatic precipitators or separators reduces the metal content in the tailings, therefore increases the value of the recovered plastic.

For example, PVC is recycled in pellets or directly reused for insulation of electric cable, insulation tape, car mats, carpet lining, flooring and footwear, etc. (about 50,000 tons per year). Copper granules is shown in figure 1.63 and before and after cable processing is shown in figure 1.64.

Figure 1.63 Copper granules

Figure 1.64 Before and after processing

1.5.2.1.6 Cable Stripping. A less costly and as environmentally sound process for material separation is cable stripping, but it is a process with much lower throughput. Such equipment is designed to handle only single strands of cable waste at rates up to 60 m/min. or 1,100 kg/min with cable that is as thin as 1.6 mm or as thick as 150 mm. In 1997, machines that operate at 24 m/min. sell for about $5,000, whereas small tabletop machines that operate at rates of only 8 m/min. sell for as little as $1,800 in the U.S.A. and Europe. These machines are manufactured in many countries.

Many of the developing countries use these machines rather than the more expensive cable chopping machines. For example, Cyprus, India, Israel, Jordan, Latvia, Lebanon, Russian Federation, Saudi Arabia, United Arab Emirates, Vietnam, Pakistan, China and others use these machines. Cable stripping machines are also used in most developed countries, where these machines are used by utilities, cable manufacturers, cable chopping companies and metal scrap dealers.

The advantages of stripping, in contrast to chopping, is the purity of the recovered jacketing and insulation materials. It is completely free of conducting metal and, if the user is careful in segregating the cable scrap before it is processed, the tailings can consist of one type of polymer. This way, the tailings, both metal and polymer, become more easily recyclable.

Processors in the developing countries have found that the stripping process is attractive, because they can recycle the tailings, such as plasticized PVC, with relative ease. The capital and operating costs for these machines are also very affordable.

1.6 Unit Cost of Material

Unit cost of newly manufactured cables are given in following tables according to the cable types.

Table 1.22 Unit cost of Coaxial Cables

Cable Types		Unit Cost YTL/kilometer	
		min	max
Coaxial Cables	75 Ω	925,00	4.600,00
	50 Ω	1.350,00	5.400,00

Table 1.23 Unit cost of Halogen Free Cables

Cable Types	Cross Section	Unit Cost YTL/kilometer	
		min	max
Halogen Free Cables	2x0.75mm^2	1.700,00	2.200,00
	2x1.00mm^2	1.950,00	2.725,00
	2x1.50mm^2	2.500,00	3.700,00
	2x2.50mm^2	3.600,00	5.600,00

Table 1.24 Unit cost of LAN&Data Cables

Cable Types	Cross Section	Unit Cost YTL/kilometer
LAN&Data Cables	2x(7x0.15)	285,00
	4x(7x0.15)	440,00
	6x(7x0.15)	585,00
	8x(7x0.15)	780,00

Table 1.25 Unit cost of Telephone Cables

Cable Types	Cable Type	Unit Cost YTL/kilometer	
		min	max
Telephone Cables	1x2x0.50+0.50	380,00	885,00
	2x2x0.50+0.50	580,00	650,00
	3x2x0.50+0.50	800,00	960,00
	4x2x0.50+0.50	980,00	1.100,00
	6x2x0.50+0.50	1.390,00	1.690,00
	10x2x0.50+0.50	2.160,00	2.650,00
	20x2x0.50+0.50	4.350,00	5.160,00
	30x2x0.50+0.50	6.350,00	7.460,00
	50x2x0.50+0.50	10.000,00	11.930,00
	100x2x0.50+0.50	19.300,00	23.000,00

Table 1.26 Unit cost of Signal&Control Cables

Cable Types	Cross Section	Unit Cost YTL/kilometer	
		min	max
Signal&Control Cables	2x0.22mm^2	460,00	1.020,00
	3x0.22mm^2	625,00	1.220,00
	4x0.22mm^2	780,00	1.365,00
	5x0.22mm^2	930,00	1.485,00
	6x0.22mm^2	1.120,00	1.800,00
	7x0.22mm^2	1.225,00	2.130,00
	8x0.22mm^2	1.420,00	2.200,00
	10x0.22mm^2	1.740,00	2.800,00
	2x0.34mm^2	600,00	1.225,00
	3x0.34mm^2	835,00	1.430,00
	4x0.34mm^2	1.040,00	1.720,00
	6x0.34mm^2	1.500,00	2.380,00
	8x0.34mm^2	1.960,00	2.890,00
	10x0.34mm^2	2.340,00	3.550,00
	2x0.50mm^2	710,00	1.370,00
	3x0.50mm^2	960,00	1.700,00
	4x0.50mm^2	1.200,00	2.000,00
	6x0.50mm^2	1.800,00	2.840,00
	8x0.50mm^2	2.340,00	3.500,00
	10x0.50mm^2	2.880,00	4.220,00
	12x0.50mm^2	3.420,00	4.350,00
	2x0.75mm^2	890,00	1.565,00
	3x0.75mm^2	1.270,00	1.910,00
	4x0.75mm^2	1.610,00	2.550,00
	5x0.75mm^2	1.980,00	3.050,00
	6x0.75mm^2	2.420,00	3.600,00
	8x0.75mm^2	3.140,00	4.300,00
	10x0.75mm^2	3.970,00	5.400,00
	12x0.75mm^2	4.720,00	6.400,00
	20x0.75mm^2	7.800,00	9.650,00

Table 1.26 Unit cost of Signal&Control Cables

Cable Types	Cross Section	Unit Cost YTL/kilometer	
		min	max
Signal&Control Cables	2x1.00mm^2	1.100,00	1.845,00
	3x1.00mm^2	1.590,00	2.360,00
	4x1.00mm^2	2.040,00	2.950,00
	5x1.00mm^2	2.500,00	3.590,00
	6x1.00mm^2	3.130,00	4.150,00
	8x1.00mm^2	4.100,00	5.000,00
	10x1.00mm^2	4.975,00	6.700,00
	12x1.00mm^2	5.900,00	7.100,00
	14x1.00mm^2	6.850,00	8.200,00
	16x1.00mm^2	7.750,00	9.600,00
	18x1.00mm^2	8.700,00	10.500,00
	20x1.00mm^2	9.700,00	12.400,00
	2x1.50mm^2	1.500,00	2.320,00
	3x1.50mm^2	2.140,00	3.050,00
	4x1.50mm^2	2.800,00	3.800,00
	5x1.50mm^2	3.600,00	4.820,00
	6x1.50mm^2	4.300,00	4.820,00
	8x1.50mm^2	5.700,00	5.750,00
	10x1.50mm^2	7.050,00	6.450,00
	12x1.50mm^2	8.450,00	7.400,00
	14x1.50mm^2	9.700,00	9.150,00
	16x1.50mm^2	11.000,00	10.600,00
	18x1.50mm^2	12.400,00	13.800,00
	20x1.50mm^2	14.000,00	16.800,00
	25x1.50mm^2	17.400,00	20.000,00
	2x2.50mm^2	2.370,00	3.480,00
	3x2.50mm^2	3.400,00	4.850,00
	4x2.50mm^2	4.600,00	6.150,00
	5x2.50mm^2	5.800,00	7.650,00
	6x2.50mm^2	6.850,00	9.150,00
	8x2.50mm^2	9.200,00	12.330,00
	10x2.50mm^2	11.800,00	15.250,00

CHAPTER TWO

EXPERIMENTAL STUDY

In the experimental part of the study, some types of waste cables are sampled for analysis to determine theoretical recovery rates for cable components.

2.1 Materials&Method

Sampling procedure: 12 different cable types are samples, mainly energy cables and telecommunication cables. Those cables are obtained from a demolished hotel located in Istanbul. 30-40 cm long cables are cut and deposited in plastic bags to transfer to the laboratory for the analysis.

Sample preparation: Cables are sorted according to their diameters and types and ~25 cm long sub sample is prepared for gravimetrical analysis. Cable dimensions (diameter and length) are measured by using compass and ruler once more, and weighted prior to the tests.

2.2 Laboratory Studies

Approximately 25 cm long cable samples are used for the analysis. First, the cable is cut along its length by using a lancet. After the outer cover (PVC) is removed, the filling material (plastic, soil, or paste) is also cut along the length to be separated. The inside lines of copper wires, which are also covered with PVC, are collected. The last step is to cut the outer PVC cover of copper or aluminum wires or woven metal, separate the metal and plastic parts. The material obtained at the end of the each step is weighted and noted.

The weights and weight distributions of the cable components for different types of cables are given in the next chapter.

CHAPTER THREE

RESULTS AND DISCUSSION

The results of the experimental studies are given in the section of the thesis.

3.1 Results

3.1.1 Energy Cable I – Ø17mm x L210mm

This cable type is used for energy transfer for low to moderate energy loads. Figure 3.1 and 3.2 show cable cross section and components of the cable. The weights of the cable components and their weight distribution are given in Table 3.1

Figure 3.1 Cross section of energy cable

Figure 3.2 Components of energy cable

Table 3.1 The material analysis for energy cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	51	
Outer covering PVC	16	31,4
Inner covering PVC	5	9,8
Rope	0	0
Protective filling material	16	31,4
Aluminium wowen wire	0	0
Aluminium	0	0
Nylon	0	0
Iron	0	0
Copper	14	27,5
TOTAL		100

3.1.2 Energy Cable II - Ø 43mm x L287mm

Figure 3.3 Cross section of energy cable

Figure 3.4 Components of energy cable

Table 3.2 The material analysis for energy cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	1255	
Outer covering PVC	145	11,6
Inner covering PVC		
green-yellow	20	1,6
brown	30	2,4
blue	29	2,3
black	31	2,5
Rope	0	0,0
Protective filling material	172	13,7
Aluminium wowen wire	0	0,0
Aluminium	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	119	9,5
in brown	233	18,6
in blue	236	18,8
in black	240	19,1
Total		100

3.1.3 Energy Cable III - Ø22mm x L267mm

Figure 3.5 Cross section of energy cable

Figure 3.6 Components of energy cable

Table 3.3 The material analysis for energy cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	275	
Outer covering PVC	50	18,2
Inner covering PVC		
green-yellow	7	2,5
brown	7	2,5
blue	7	2,5
black	7	2,5
Rope	0	0,0
Protective filling material	53	19,3
Aluminium wowen wire	0	0,0
Aluminium	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	36	13,1
in brown	36	13,1
in blue	36	13,1
in black	36	13,1
Total		100

3.1.4 Energy Cable IV - Ø 28mm x L190mm

Figure 3.7 Cross section of energy cable

Figure 3.8 Components of energy cable

Table 3.4 The material analysis for energy cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	1208	
Outer covering PVC	100	8,3
Inner covering PVC		
green-yellow	15	1,2
brown	26	2,2
blue	26	2,2
black	27	2,2
Rope	0	0,0
Protective filling material	212	17,5
Aluminium wowen wire	0	0,0
Aluminium	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	108	8,9
in brown	229	19,0
in blue	234	19,4
in black	231	19,1
Total		100

3.1.5 Energy Cable V - Ø32 mm x L225mm

Figure 3.9 Cross section of energy cable

Figure 3.10 Components of energy cable

Table 3.5 The material analysis for energy cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	**418**	
Outer covering PVC	62	14,8
Inner covering PVC		
green-yellow	6	1,4
brown	12	2,9
blue	12	2,9
black	12	2,9
Rope	0	0,0
Protective filling material	83	19,9
Aluminium wowen wire	0	0,0
Aluminium	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	31	7,4
in brown	67	16,0
in blue	66	15,8
in black	67	16,0
Total		100

3.1.6 Coaxial Cable I - Ø16mm x L195mm

Figure 3.11 Cross section of coaxial cable

Figure 3.12 Components of coaxial cable

Table 3.6 The material analysis for coaxial cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	25	
Outer covering PVC	10	40,0
Inner covering PVC	9	36,0
Rope	0	0,0
Protective filling material	0	0,0
Aluminum woven wire	0	0,0
Aluminum	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper	6	24,0
Total		100

3.1.7 Telephone Cable I - Ø29mm x L265mm

Figure 3.13 Cross section of telephone cable

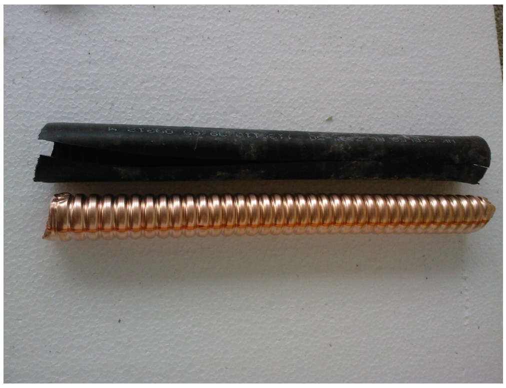


Figure 3.14 Components of telephone cable

Table 3.7 The material analysis for Telephone cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	128	
Outer covering PVC	30	23,4
Inner covering PVC	0	0,0
Rope	0	0,0
Protective filling material	0	0,0
Aluminum woven wire	0	0,0
Aluminum	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper	98	76,6
Total		100

3.1.8 Telephone Cable II - Ø11mm x L350mm

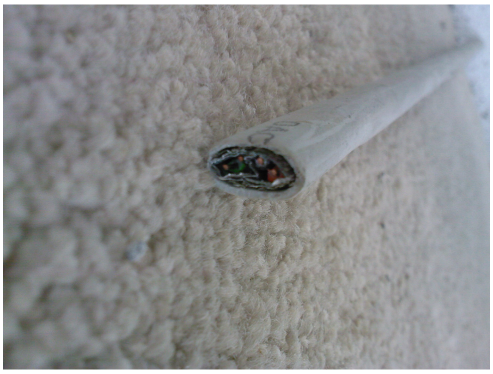


Figure 3.15 Cross section of telephone cable

Figure 3.16 Components of telephone cable

Table 3.8 the material analysis for telephone cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	**27**	
Outer covering PVC	15	55,6
Inner covering PVC		
orange	1	3,7
green	1	3,7
red	1	3,7
black	1	3,7
Rope	0	0,0
Protective filling material	0	0,0
Aluminum woven wire	2	7,4
Aluminum	2	7,4
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	1	3,7
in brown	1	3,7
in blue	1	3,7
in black	1	3,7
Total		100

3.1.9 Telephone Cable III - Ø5mm x L367mm

Figure 3.17 Cross section of telephone cable

Figure 3.18 Components of telephone cable

Table 3.9 The material analysis for Telephone cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	**18**	
Outer covering PVC	3	16,7
Inner covering PVC	0	0,0
Rope	1	5,6
Protective filling material	0	0,0
Aluminum woven wire	0	0,0
Aluminum	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper	14	77,8
Total		100

3.1.10 Data Cable I - Ø10mm x L197mm

Figure 3.19 Cross section of data cable

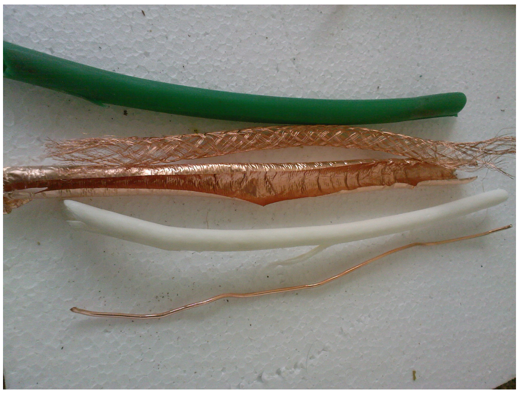


Figure 3.20 Components of data cable

Table 3.10 The material analysis for data cable

Parts of the Cable	**Weights of the parts, g**	**Weight distribution, %**
Initial Sample Weight	**1255**	
Outer covering PVC	145	11,6
Inner covering PVC		
green-yellow	20	1,6
brown	30	2,4
blue	29	2,3
black	31	2,5
Rope		0,0
Protective filling material	172	13,7
Aluminum woven wire	0	0,0
Aluminum	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	119	9,5
in brown	233	18,6
in blue	236	18,8
in black	240	19,1
Total		100

3.1.11 Underground Cable I - Ø34mm x L592mm

Figure 3.21 Cross section of underground cable

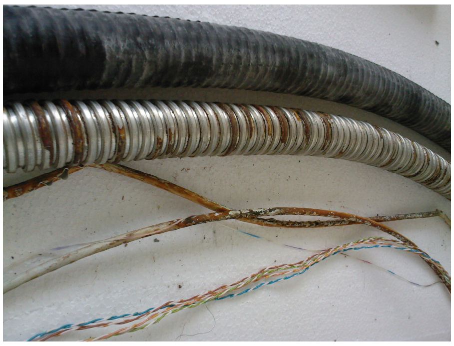


Figure 3.22 Components of underground cable

Table 3.11 The material analysis for underground cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	**374**	
Outer covering PVC	179	47,9
PVC 1	6	1,6
PVC 2	6	1,6
Rope	0	0,0
Protective filling material	0	0,0
Aluminum woven wire	0	0,0
Aluminum	0	0,0
Nylon	0	0,0
Iron	163	43,6
Copper	20	5,3
Total		100

3.1.12 Underground Cable II - Ø19mm x L150mm

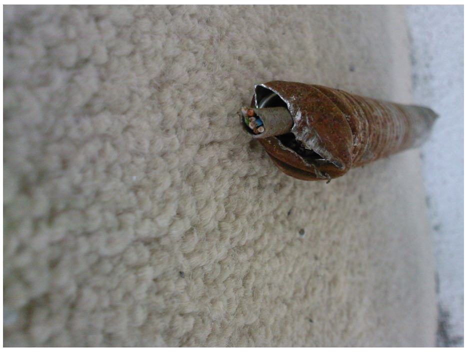


Figure 3.23 Cross section of underground cable

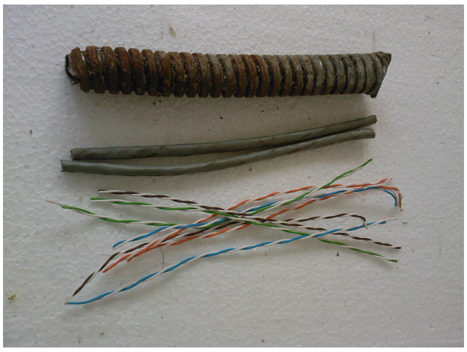


Figure 3.24. Components of underground cable

Table 3.12 The material analysis for telephone cable

Parts of the Cable	Weights of the parts, g	Weight distribution, %
Initial Sample Weight	**831**	
Outer covering PVC	1,5	0,2
Inner covering PVC	1,5	0,2
Rope	0	0,0
Protective filling material	0	0,0
Aluminum woven wire	0	0,0
Aluminum	0	0,0
Nylon	0	0,0
Iron	0	0,0
Copper		
in green-yellow	119	14,3
in brown	233	28,0
in blue	236	28,4
in black	240	28,9
Total		100

3.2 Discussion

The results of the study for Energy Cables and Telephone Cables are discussed in this part, as well as Coaxial Cables, Data Cables, and Underground Cables.

According to the data obtained in part 3.1 a budget is built for each type of the cables. The valuable (recyclable) materials and the waste materials are taken into the consideration for this budget. The prices of copper and aluminum components of the cables are obtained from London Metal Exchange (LME) at the date of 25th of July, iron component price is obtained from Ekor Recycling Company, Izmir, the recycled PVC price is obtained from Bilge Metal Company, Bursa which produces PVC hoses, and the disposal price of the wasted hazardous materials (Protective Filling Material and Rope) are obtained from IZAYDAS Hazardous Waste Disposal Facility, Izmit in July, 2008. The weight percentage of each cable components is multiplied by its market price and the sum of the results are displayed to show final market price of a used cable. Disposal prices are displayed with a negative (-) symbol in the budget. The budgets for the studied cables are given in following tables.

Table 3.13 Energy cable, Ø17 mm L210 mm

Market price of cable components	Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	41	7990	27	415	0	2907	0	-149	31
The cost of the scrap materials ($/t)	61		2193		0		0		-47	
The Income Obtained from Used Cable ($/t) = 2208										

Table 3.14 Energy cable, Ø43 mm 287 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	20	7990	66	415	0	2907	0	-149	14
The cost of the scrap materials ($/t)	30		5273		0		0		-20	
The Income Obtained from Used Cable ($/t) = 5283										

Table 3.15 Energy cable, Ø22 mm 267 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	28	7990	52	0	0	2907	0	-149	19
The cost of the scrap materials ($/t)	42		4187		0		0		-29	
The Income Obtained from Used Cable ($/t) = 4200										

Table 3.16 Energy cable, Ø28 mm 190 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	16	7990	66	415	0	2907	0	-149	18
The cost of the scrap materials ($/t)	24		5305		0		0		-26	
The Income Obtained from Used Cable ($/t) = 5303										

Table 3.17 Energy cable, Ø32 mm 225 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	25	7990	55	415	0	2907	0	-149	20
The cost of the scrap materials ($/t)	37		4410		0		0		-30	
The Income Obtained from Used Cable ($/t) = 4418										

Table 3.18 Coaxial cable, Ø16 mm 195 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	76	7990	24	0	0	2907	0	-149	0
The cost of the scrap materials ($/t)	113		1918		0		0		0	
The Income Obtained from Used Cable ($/t) = 2031										

Table 3.19 Telephone cable, Ø29 mm 265 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	23	7990	77	415	0	2907	0	-149	0
The cost of the scrap materials ($/t)	35		6120		0		0		0	
The Income Obtained from Used Cable ($/t) = 6155										

Table 3.20 Telephone cable, Ø11 mm 350 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	70	7990	15	415	0	2907	15	-149	0
The cost of the scrap materials ($/t)	105		1183		0		430		0	
The Income Obtained from Used Cable ($/t) = 1718										

Table 3.21Telephone cable, Ø5 mm 367 mm

Market price of cable components	**Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages**									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	22	7990	78	0	0	2907	0	-149	0
The cost of the scrap materials ($/t)	33		6216		0		0		0	
The Income Obtained from Used Cable ($/t) = 6250										

Table 3.22 Data cable , Ø10 mm 97 mm

Market price of cable components	Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	20	7990	66	415	0	2907	0	-149	14
The cost of the scrap materials ($/t)	30		5273		0		0		-20	
The Income Obtained from Used Cable ($/t) = 5283										

Table 3.23 Underground cable, Ø34 mm 592 mm

Market price of cable components	Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	51	7990	5	415	44	2907	0	-149	0
The cost of the scrap materials ($/t)	76		423		181		0		0	
The Income Obtained from Used Cable ($/t) = 681										

Table 3.24 Underground cable, Ø19 mm 150 mm

Market price of cable components	Scrap Materials Recovered From Energy Cables and their Unit Price and Weight Percentages									
	PVC		Copper		Iron		Aluminium		Pro.Fill.Mat.	
	$/t	%	$/t	%	$/t	%	$/t	%	$/t	%
	149	0	7990	100	415	0	2907	0	-149	0
The cost of the scrap materials ($/t)	0		7958		0		0		0	
The Income Obtained from Used Cable ($/t) = 7959										

The results from the budget are used to evaluate the data obtained from the material recovery analysis.

When the Energy Cables are taken to the consideration, as can be seen from the Figure 3.25, final price of the used cable is increasing with increasing amount of recyclables recovered from the cable. Figure 3.25 also displays the distribution of recyclables originated from used Energy Cables and it is seen that the market price of the used cables also increase with increasing cable diameter (Figure 3.25).

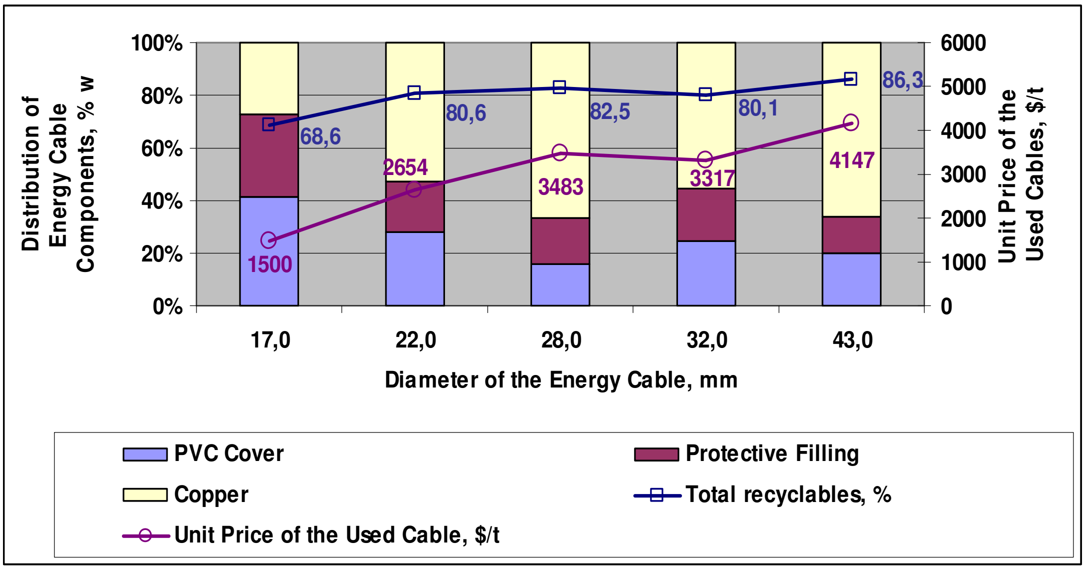


Figure 3.25 Material Distribution and Final Price of Used Energy Cables

The increase in the final price with increasing diameter can be explained with increasing copper content of the cable. Amount of PVC is not a factor to determine the price of a used cable, but the price is a function of the copper amount that the cable contains.

The situation for telephone cables is also evaluated. Figure 3.26 shows the components distribution and the prices for telephone cables with different diameters.

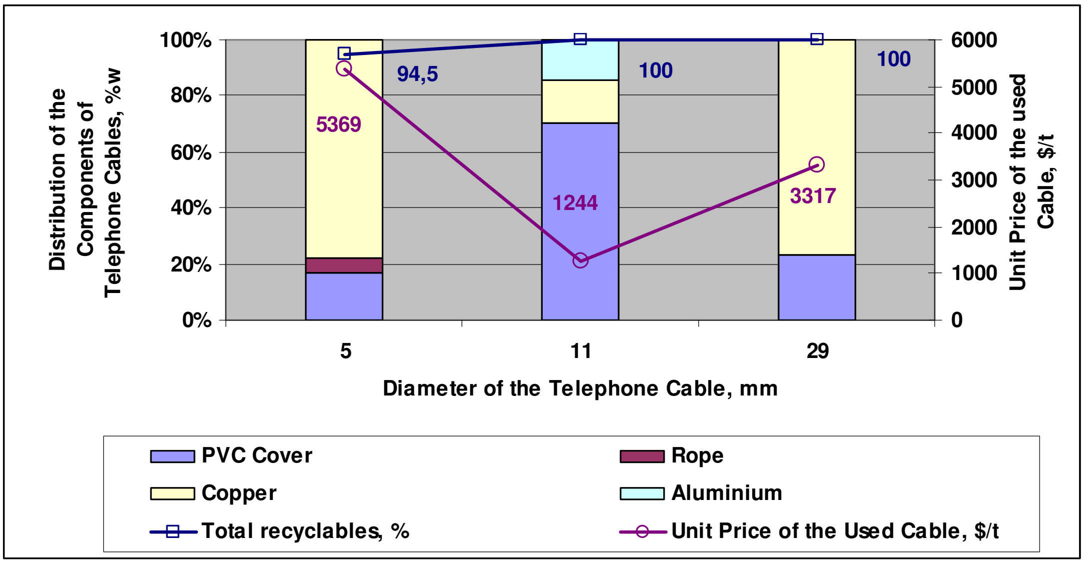


Figure 3.26 Material Distribution and Final Price of Used Telephone Cables

As can be seen in Figure 3.26, any component, except the rope, can be recycled when the telephone cables are considered. Here the effect of copper content on the used cable prices can be seen much clearer. The telephone cable with 11 mm diameter can be 100% recycled, but since its copper content is low (15 %), its final price is much lower.

Since more data obtained for Energy Cables, its components are investigated in details. The following figures (Figures 3.27 – 3.30) displays the correlations between the weight percentages of the cable components and cable diameters.

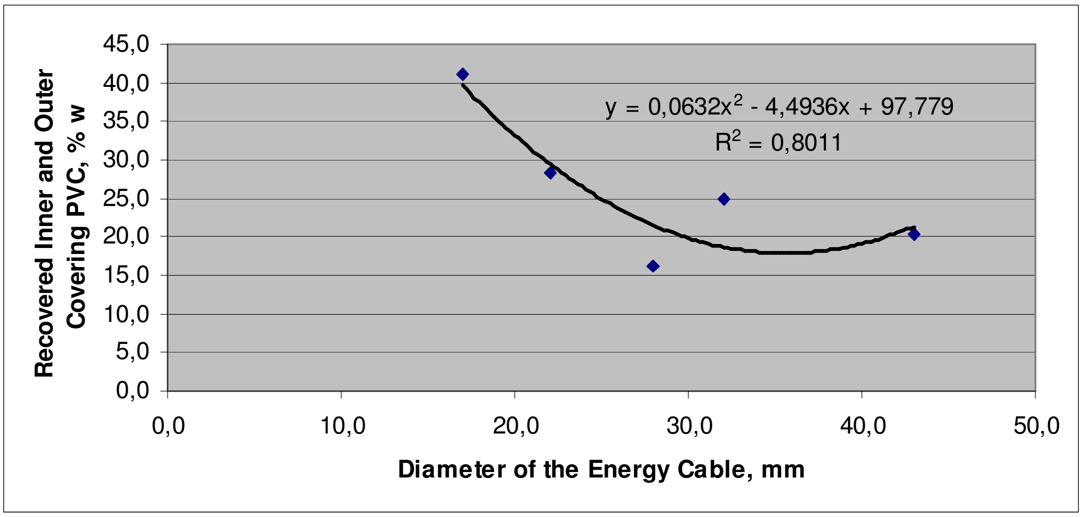


Figure 3.27 The PVC obtained from Energy Cables According to Cable Diameter

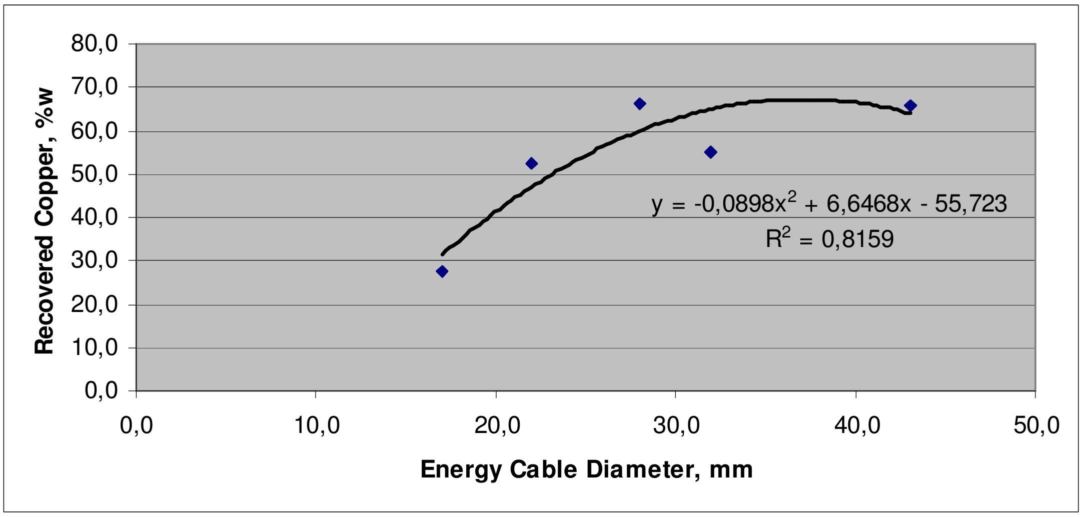


Figure 3.28 The Copper obtained from Energy Cables According to Cable Diameter

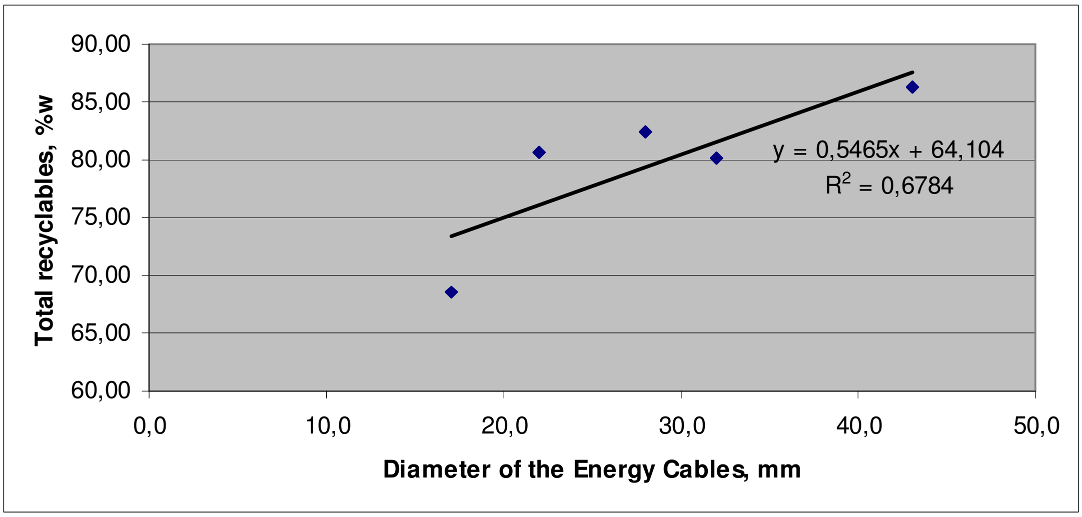


Figure 3.29 Total Recyclables obtained from Energy Cables According to Cable Diameter

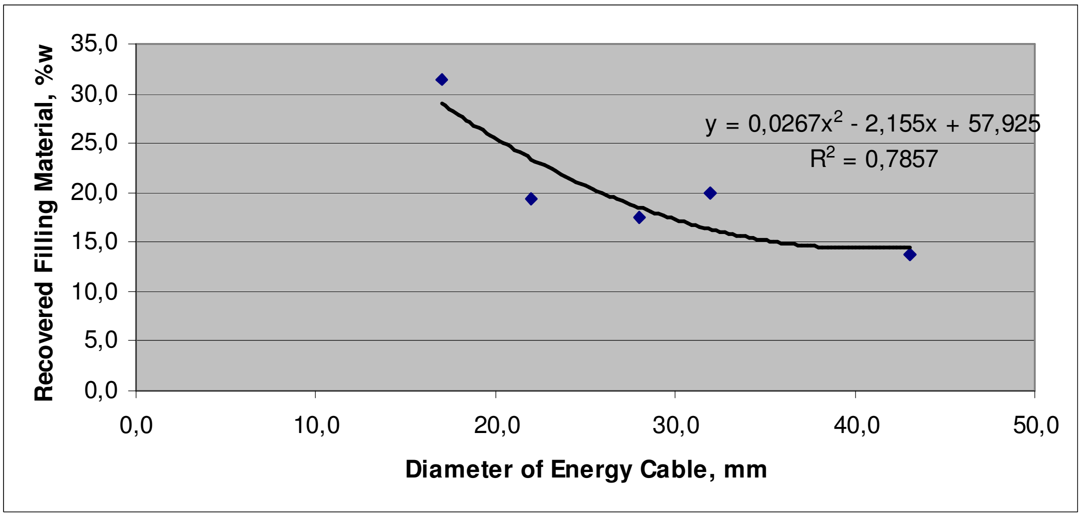


Figure 3.30 The Protective Filling Material (Hazardous Waste) from Energy Cables According to Cable Diameter

As can be seen from the figures above, PVC obtained from the energy cables are decreasing with increasing diameter. Oppositely, recovered copper is increasing with increasing diameter. This can be explained by the correlations between the diameter of a circle and its perimeter and area. The equation with diameter (D) and perimeter (P) is $P=\pi*D$ while the equation with diameter and area (A) is $A= \pi*D^2$. So, while the diameter increases 2 units, perimeter increases 2 units, but the area increases 4 units. That means, the cables with larger diameters have much spaces to keep more copper wires. Since the number of copper wires increases with increasing diameter, there is not much space to place protective filling material (Figure 3.30).

The prices of the used cables for the recycling companies are different than the final price of the cable. The difference between these two priced determined the profit of the company when the transport and operational expenses are not taken into consideration. Table 3.25 and 3.26 shows the opportunities in the market of Cable Recycling.

Table 3.25 Market actions of used Energy Cables

Diameter, mm	**17,0**	**22,0**	**28,0**	**32,0**	**43,0**
Income obtained from used cable recycling, $/t	2208	4200	5303	4418	5283
The sale price of used cables, $/t	1244	2654	3483	3317	4147
Profit $/t (except transport and operational costs)	964	1546	1820	1101	1136

Table 3.26 Market Actions for Telephone Cables

Diameter, mm	**5**	**11**	**29**
Income obtained from used cable recycling, $/t	6250	1718	6155
The sale price of used cables, $/t	5369	1244	3317
Profit $/t (except transport and operational costs)	781	474	2838

CHAPTER FOUR

CONCLUSION

The market capacity of cable production sector in the world is 500 million $ with 370 active companies in Turkey. A medium scaled used cable recycling company located in Aegean Region can process 35.000 tons/year of scrap cable. That value can explain extend of the cable recycling market in Turkey.

Material recovery form used cables is one of the best working recycling investments, since the raw material is plenty and easy to obtain.

When the total production rate in the world and average life time of a cable (approx. 10 years) is considered, it is seen that cable recycling is very important for material recovery.

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APPENDICES

Appendix I International Trademarks of Cable Standards according to the countries they are applied.

SHORT NAME	COUNTRY	DESCRIPTION
AFNOR	FRANCE	Association Française de NORmalisation
ANSI	USA	American National Standards Institute
AS	AUSTRALIA	Australian Standard
ASTM	USA	American Standard of Testing Materials
BS	GREAT BRITAIN	British Standard
BSI	GREAT BRITAIN	British Standard Institution
BV	FRANCE	Bureau Veritas
CATV	INTERNATIONAL	Community Antenna Television
CEBEC	BELGIUM	Comite Electrotechnique Belge
CEE	INTERNATIONAL COMMISSION	International Commission on Ruls for the Approval of Electrical Equipment
CEI	INTERNATIONAL	Commission Electrotechnique Internationale
CEMP	FRANCE	Centre d'Etude des Matieres Plastiques
CEN	EUROPE	Comite Europeen de Normalisation Electrotechniques
CENELEC	EUROPE	Comite Europeen de Normalisation Electrotechniques
CNET	FRANCE	Centre National d'Etude de Telecommunication
CNOMO	FRANCE	Comite de Normalisation des Moyens de Production
CSA	CANADA	Canadian Standards Association
CSTB	FRANCE	Centre Scientifique et Technique du Batiment
DEMKO	DENMARK	Danmarks Elektriske Material Kontrol
DIN	GERMANY	Deutsches Institut für Normung
DKE	GERMANY	Deutsche Elektrotechnische Kommission im DIN und VDE
EN	GERMANY	European Standards
FAR	USA	Federal Air Regulation
FTZ	GERMANY	Fernmeldetechnisches Zentralamt
GOST	USSR	USSR-Standards
HD	INTERNATIONAL	Harmonisierungs-Dokumente
HN	FRANCE	Harmonisation des Normes
IEC	INTERNATIONAL	International Electrotechnical Commission
IEE	GREAT BRITAIN	Institution of Electrical Engineers
IEEE	GREAT BRITAIN	Institute of Electrical and Electronic Engineers
ISDN	INTERNATIONAL	Integrated Services Digital Network

ISO	INTERNATIONAL	International Organisation for Standardization
KEMA	NETHERLANDS	Keuring van Elektrotechnische Materialien
LCIE	FRANCE	Laboratorie Central des Industries electriques
MIL	USA	Military Specification
NEC	USA	National Electrical Code
NEMA	USA	National Electrical Manufacturers Association
NEMKO	NORWAY	Norges Elektriske Materiell Kontroll
NEN	NETHERLANDS	Nederlands Normalisatie-Instituut
NF	FRANCE	Normes Françaises
NFC	FRANCE	Normes Françaises Class C
ÖVE	AUSTRIA	Österreichischer Verband für Elektrotechnik
SAE		Society of Automotive Engineers
SEK	SWEDEN	Svenska Elektriska Kommissionen
SEMKO	SWEDEN	Svenska Elektriska Materiel Kontrollanstalten
SETI	FINLAND	Sahkötarkastuslatios
SEV	SWITZERLAND	Schweizerischer Elektrotechnischer Verein
SNV	SWITZERLAND	Schweizerischer Normenverband
TSE	TURKEY	Türk Standardları Enstitüsü
UL	USA	Underwriters Laboratories Inc.
UNI	ITALY	Unificazione Nationale Italiana
UTE	FRANCE	Union Technique de I'Electricite
VDE	GERMANY	Verein Deutscher elektroingenieure
VDEW	GERMANY	Vereinigung Deutscher Elektrizitatswerke e.V.
ZVEH	GERMANY	Zentralverband der Deutschen Elektrohandwerke e.V.
ZVEI	GERMANY	Zentralverband der Elektrotechnik-und Elektronik Industrie e.V.

Appendix II Cable Designation for harmonised cable Symbols and explanations in harmonise system

1	2	3	4	5	6	7	8	9
H	05	V	V		F	4	G	2,5

1. **Basic Types**
    a. H Harmonised type
    b. A National type
2. **Rated Voltage**
    a. 03 300/300V
    b. 05 300/500V
    c. 07 450/750V
3. **Insulation Material**
    a. V PVC
    b. R Rubber
    c. S Silicon Rubber
4. **Sheath Material**
    a. V PVC
    b. R Rubber
    c. N Ploychloroprene
    d. J Fibre-glass braid
    e. T Textile Braid
5. **Special Constructions**
    a. H Flat with divisible
    b. H2 Flat non-divisible
6. **Conductor Form**
    a. U Solid conductor
    b. R Stranded conductor
    c. K Fine wire conductor (Permanent installtion)
    d. F Fine wire conductor (Flexible)
    e. H Super-fine wire conductor
7. **Number of Cores**
    a. …. Number of cores
8. **Protective Conductor**
    a. X Without protective conductor
    b. G With protective conductor
    c. N Ploychloroprene
9. **Conductor cross-section in mm_**

Appendix III Core Colors, VDE	
Core Numbers	Core Colors
1	Any color
2	Brown - Blue
3	Green/Yellow - Brown - Blue or Black -Blue - Brown
4	Green/Yellow - Black - Blue - Brown or Black - Blue - Brown - Black
5	Green/Yellow - Black - Blue - Brown - Black or Black - Blue - Brown - Black - Black
6 and more	Green/Yellow - other cores black and number codes or Green/Yellow - other cores black and number codes

Appendix IV Core Colors, HAR	
Core Numbers	Core Colors
1	Any color
2	Light Blue – Black
3	Green/Yellow - Light Blue - Brown or Light Blue - Black – Brown
4	Green/Yellow - Light Blue - Black - Brown or Light Blue - Black - Brown – Black
5	Green/Yellow - Light Blue - Black - Brown - Black or Light Blue - Black - Brown - Black – Black
6 and more	Green/Yellow - other cores in different colors or Green/Yellow - other cores black and number codes

Appendix V Color Codes according to DIN 47100

Core Nr	Insulation Color Codes
1	WHITE
2	BROWN
3	GREEN
4	YELLOW
5	GREY
6	PINK
7	BLUE
8	RED
9	BLACK
10	VIOLET
11	GREY / Pink
12	RED / Blue
13	WHITE / Green
14	BROWN / Green
15	WHITE / Yellow
16	YELLOW / Brown
17	WHITE / Grey
18	GREY / Brown
19	WHITE / Pink
20	PINK / Brown
21	WHITE / Blue
22	BROWN / Blue
23	WHITE / Red
24	BROWN / Red
25	WHITE / Black
26	BROWN / Black
27	GREY / Green
28	YELLOW / Grey
29	PINK / Green
30	YELLOW / Pink
31	GREEN / Blue
32	YELLOW / Blue
33	GREEN / Red
34	YELLOW / Red
35	GREEN / Black
36	YELLOW / Black
37	GREY / Blue
38	PINK / Blue
39	GREY / Red
40	PINK / Red
41	GREY / Black
42	PINK / Black
43	BLUE / Black
44	RED / Black

Twisted Pairs		
Core Nr.	Insulation Color Codes	
	Core A	Core B
1	WHITE	BROWN
2	GREEN	YELLOW
3	GREY	PINK
4	BLUE	RED
5	BLACK	VIOLET
6	GREY / Pink	RED / Blue
7	WHITE / Green	BROWN / Green
8	WHITE / Yellow	YELLOW / Brown
9	WHITE / Grey	GREY / Brown
10	WHITE / Pink	PINK / Brown
11	WHITE / Blue	BROWN / Blue
12	WHITE / Red	BROWN / Red
13	WHITE / Black	BROWN / Black
14	GREY / Green	YELLOW / Grey
15	PINK / Green	YELLOW / Pink
16	GREEN / Blue	YELLOW / Blue
17	GREEN / Red	YELLOW / Red
18	GREEN / Black	YELLOW / Black
19	GREY / Blue	PINK / Blue
20	GREY / Red	PINK / Red
21	GREY / Black	PINK / Black
22	BLUE / Black	RED / Black
≥ 23 pairs and above: pair colors repeat.		